

THE BIG SCIENCE ISSUE

POPULAR SCIENCE

THE
FUTURE
NOW

SUPERSIZED

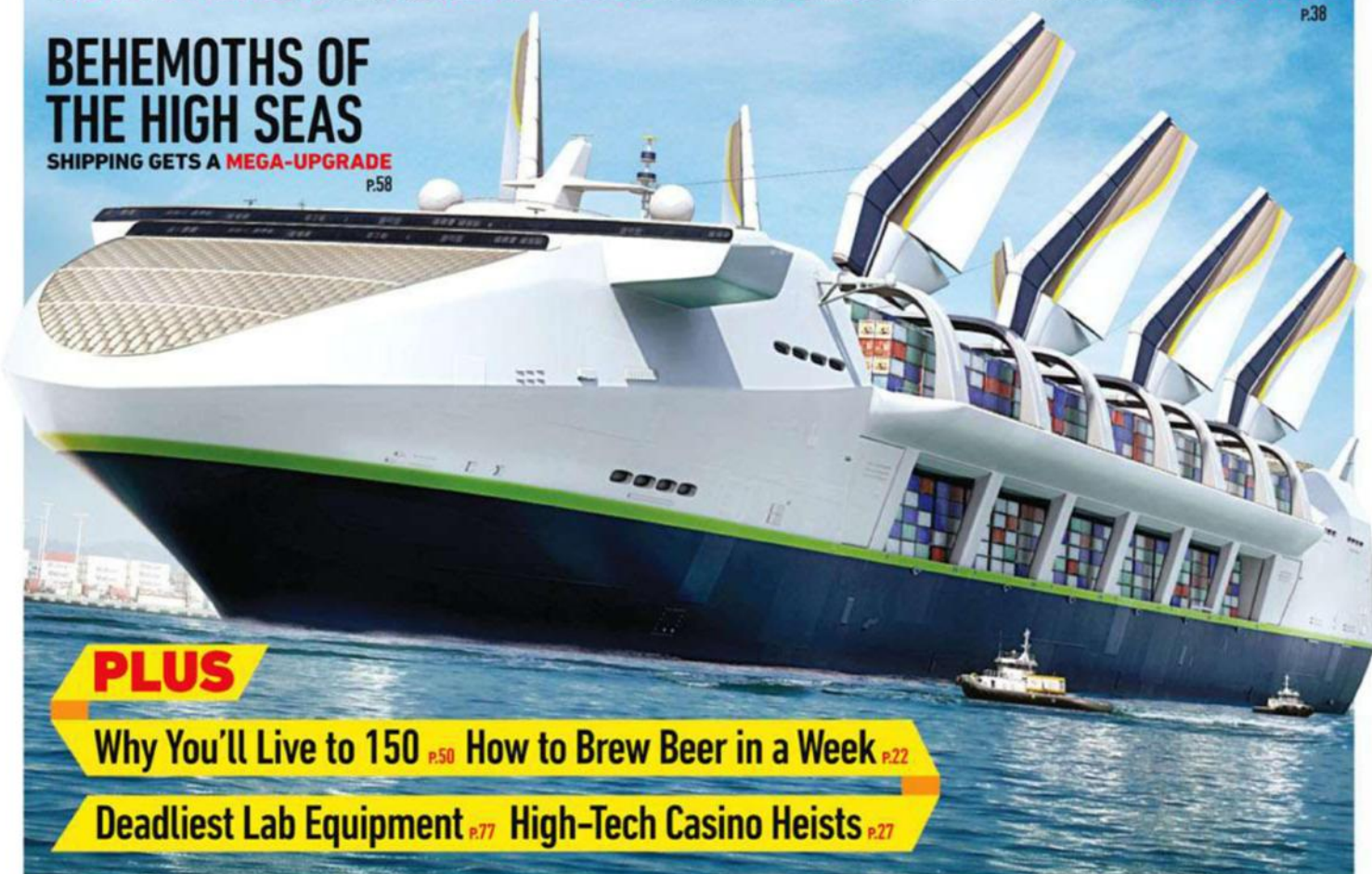
THE 10 MOST AWE-INSPIRING PROJECTS IN THE UNIVERSE

THE ULTIMATE TELESCOPE LASER PARTICLE ACCELERATOR ORBITAL LAB COLLIDER UNDERSEA OBSERVATORY AND MUCH MORE

p.38

BEHEMOTHS OF THE HIGH SEAS

SHIPPING GETS A MEGA-UPGRADE
p.58



PLUS

Why You'll Live to 150 p.50 How to Brew Beer in a Week p.22

Deadliest Lab Equipment p.77 High-Tech Casino Heists p.27

CONTENTS

THIS MONTH'S GUIDE TO INNOVATION AND DISCOVERY



AUGUST '11
VOLUME 279 #2

FEATURES

THE COUNTDOWN

38 BIG SCIENCE!

We've found the 10 grandest science projects on Earth: the ultimate laser, telescope, undersea observatory and more.

THE OBSESSIVES

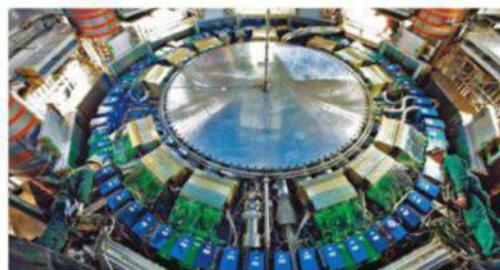
50 THE MAN WHO WOULD STOP TIME

Bill Andrews says he can develop a drug that halts aging. There's just one hitch: No one knows if it will kill us or make us live longer. **By Joseph Hooper**

THE FUTURE OF SHIPPING

58 THE SYSTEM OF THE WORLD

Cargo shipping is undergoing a major overhaul that includes new routes, bigger, more fuel-efficient ships, anti-piracy innovations and even the expansion of the Panama Canal. **By Rena Marie Pacella**



THE SYSTEM 0

The basic unit of the global economy is the humble container. Every year, a vast fleet of freighters hauls more than 17 million of them to destinations around the world. Now the ships are getting bigger, the routes are getting better, and the ports are getting smarter than ever before. What's next for the system that moves most of the stuff on Earth? **BY RENA MARIE PACELLA**

SEA CHANGE A new generation of designers [see page 61] is reimagining how container ships can move more things more places, more quickly.



F THE WORLD



BASIC UNITS

A sensor-packed shipping container that folds flat in 30 seconds

In the half-century since Malcom McLean, an entrepreneurial former trucker from North Carolina, first began packing freight onto ships in uniform steel boxes, shipping containers have transformed the way we move most of the goods on Earth. As McLean recognized, cargo with consistent dimensions becomes a commodity. Any box can go anyplace on any ship, and therefore can be moved and stored far more cheaply and quickly than cargo that comes in a hodgepodge of shapes and sizes.

The containers themselves have not changed much in 50 years, though. They are still 20 or 40 feet long, and they are still heavy, rust-prone and dumbly inert. Dutch inventor René Giesbers might have the perfect update: a light, collapsible container called the Cargoshell, made of composite materials that are transparent to security scanners and tracking sensors. Giesbers has competition, however, including the U.S. Department of Homeland Security, which has spent approximately \$60 million to design its own composite containers and new sensors. Some of these features should start appearing in the global supply chain in the next few years.

COMPOSITE BODY

As strong as steel and up to five times as corrosion-resistant, fiber-reinforced polymer walls make the box lighter and easier to scan than today's containers.

MONITORS

Internal sensors measure humidity, atmospheric pressure, oxygen level, radiation and temperature to detect food spoilage, smuggled nuclear material or even the presence of humans inside.

COLLAPSIBLE FRAME

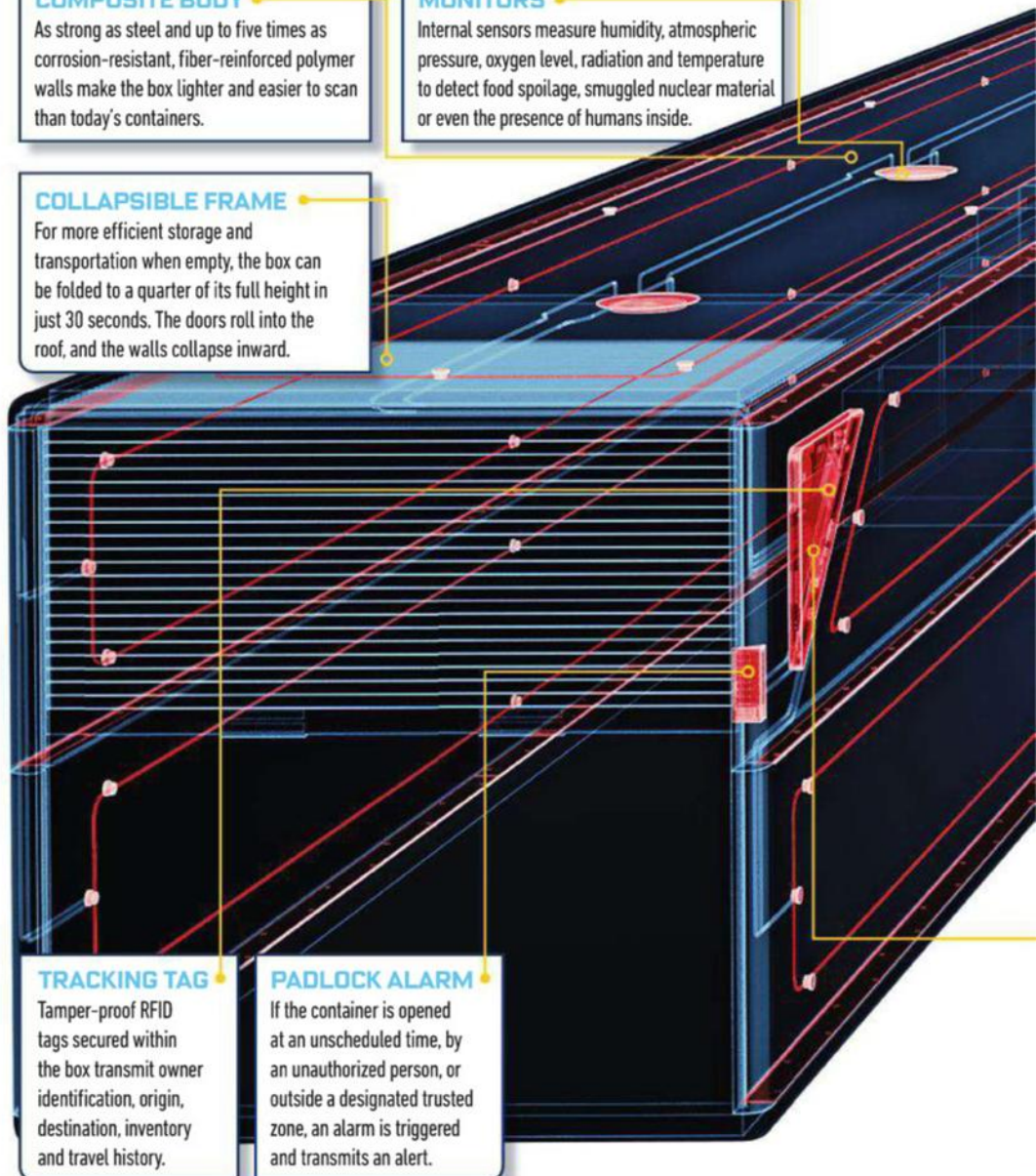
For more efficient storage and transportation when empty, the box can be folded to a quarter of its full height in just 30 seconds. The doors roll into the roof, and the walls collapse inward.

TRACKING TAG

Tamper-proof RFID tags secured within the box transmit owner identification, origin, destination, inventory and travel history.

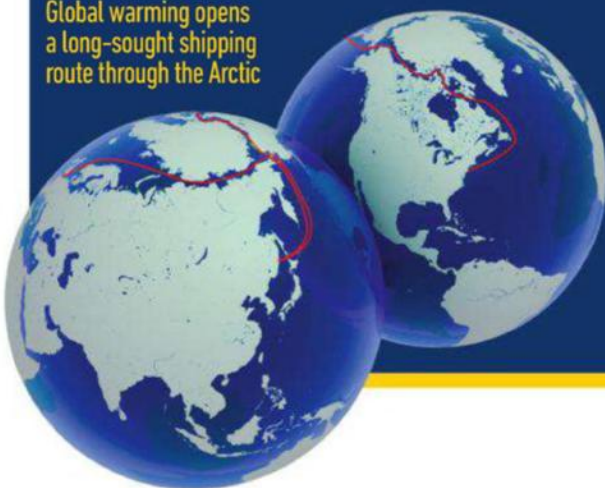
PADLOCK ALARM

If the container is opened at an unscheduled time, by an unauthorized person, or outside a designated trusted zone, an alarm is triggered and transmits an alert.



SHORT CUTS

Global warming opens a long-sought shipping route through the Arctic



For a few short weeks last September, the Northwest and Northeast Passages through the Arctic Ocean were simultaneously ice-free from end to end, the first such clearing in the time that satellites have monitored the region. Merchants have long sought routes through the ice-packed waters that link the Pacific and Atlantic. But researchers at the Naval Postgraduate School in Monterey, California, say that we could now

see an entire Arctic Ocean, not just passages along the coasts, with ice-free summers, as soon as 2016.

That is a bleak environmental scenario. But it also means that cargo ships could shave thousands of miles off their journeys. Already, Russia is touting the Northeast Passage (a.k.a. the Northern Sea Route), which hugs its Arctic coast, as a shorter, safer alternative to the pirate-infested waters near Egypt's Suez Canal. The country's



MOVING IN BULK

Imagining (and in some cases building) much bigger and more efficient carriers

Green Giant

Once it is completed, the \$190-million Maersk Triple E will be the world's largest and most efficient class of container ships. Its 1,312-foot-long, U-shaped hull will hold 18,000 containers—about 2,000 more than the next biggest ship. Whereas most container ships are propelled by a single diesel engine, the Triple E has two. But even traveling at 19 knots, it will require only half as much fuel to deliver its cargo, in part because of recovery of engine waste heat. South Korea-based Daewoo Shipbuilding and Marine Engineering will complete the first 10 for Maersk by 2015.



Natural Gas

The Quantum 9000, now just a concept from the Norwegian ship-standards firm DNV, would be the first container ship to run on liquid natural gas, or LNG, the cleanest available marine fossil fuel. Making the switch would reduce carbon dioxide emissions by 30 percent, nitrogen oxide emissions by 80 percent, and sulfur oxide emissions by 95 percent. The Quantum 9000 would be "midsized"—that is, big enough to carry nearly 9,000 containers in its 1,030-foot-long hull but still small enough to fit through the soon-to-be expanded Panama Canal [see page 63].



Modular Hybrid

When the 8,000-container NYK Super Eco Ship arrives at a port, it splits into four segments. The middle two units dock, and the forward and aft sections reconnect and move on to pick up two new, fully stocked middle sections. The 1,158-foot-long Eco Ship concept, designed by Japanese shipping line NYK, would get most of the power needed to drive its electric propellers from container-size LNG fuel cells that the crew can swap out or add like cargo. Solar cells blanketing the entire upper decks and sides and eight retractable telescoping masts with lightweight airfoil sails provide the rest.



Transformer

German logistics engineer Volker Rosenkranz proposes the CargoXpress, a 200-container catamaran that transforms into a sailboat at sea and into a high-capacity loading crane when docked, making it perfect for short hauls between small ports. In favorable winds, the 203-foot-long superstructure flap would open like a clamshell to serve as a giant sail-wing; solar cells would give the electric-motor-driven propellers an extra boost of clean energy. At port, the superstructure would extend a cantilevered crane over the dock to transfer containers directly from ship to shore.



Wind Rider

The four-masted 377-foot-long Eco-liner from Dutch shipbuilder Fair Transport B.V. may be the first of a new fleet that uses sails for primary propulsion. Unlike traditional sailing ships with crisscrossing lines and rigging, the Eco-liner has four free-standing sails, each of which electronically rotates to achieve the best angle. When there's not enough wind, a diesel-electric engine kicks in to power a propeller. The Eco-liner, which can transport 200 containers using up to 90 percent less fuel than a similar-sized conventional vessel, could haul its first load by fall 2013.



TAMPER PROTECTION

A small electrical current runs through mesh embedded in the composite walls. Any breach that disturbs the flow of current will send an alert to the shipper, the receiver and the authorities at the destination port.

COMMUNICATIONS CENTER

An onboard computer draws data from monitors and sends encrypted updates by satellite or cellular network to the appropriate parties—owners, shippers, customs officials or port operators.

fleet of for-hire, icebreaker escorts are on duty, and more are on order. Although the major container shipping lines have yet to test the icy waters, more local cargo ships and tankers have been traversing the passage recently.

Equally desired is a shipping lane through the less-developed Northwest Passage on the Canadian side of the Arctic. Although a labyrinth of frozen islands makes transit more challenging, China

could get goods to the East Coast of the U.S. without a lengthy detour through the Panama Canal or an overland trip by railroad. Similarly, travel between the Northwest U.S. and Europe would be some 2,000 miles shorter. Many climate scientists say the Northwest could become passable on a regular basis by 2020.

Designers such as Aker Arctic, a Finnish firm, are developing ships that could travel the new routes even in the off-season, including icebreakers

that can move sideways to blast channels for big cargo ships, and container ships with reinforced sterns that plow through ice rear-end first so they don't need an icebreaker to accompany them. Meanwhile, the Arctic Regional Hydrographic Commission, formed last October, is coordinating efforts to map the more than 90 percent of Arctic waters for which nautical charts are decades out of date or nonexistent.



UNLOADING THE BOX

New port systems will almost completely eliminate the need for human labor. Nothing will be run manually because of the enormous complexity of moving the volume of cargo that future mega-ports will handle. The only human intervention will be at the network-engineering level, such as fixing software glitches and monitoring the integrity of computer hardware.

Control station

At least 24 hours before docking, a ship sends an electronic cargo manifest to the terminal's manager program (A), which coordinates and queues up the duties of the hundreds of autonomous machines needed to unload and reload a ship.

Seafloor scanners

As a ship enters the port, it must first pass through a pair of sonar arrays (B) on the seafloor that scan the bottom of the vessel for irregular shapes that could be bombs or smuggled goods hidden on the hull.

Wave energy

Offshore energy collectors (hydraulic buoys (C) and floating piston pumps (D)) located near the shore capture the energy from surface waves. Generators convert that energy into electricity and transmit it to shore by way of seafloor cables.

Plug-in power

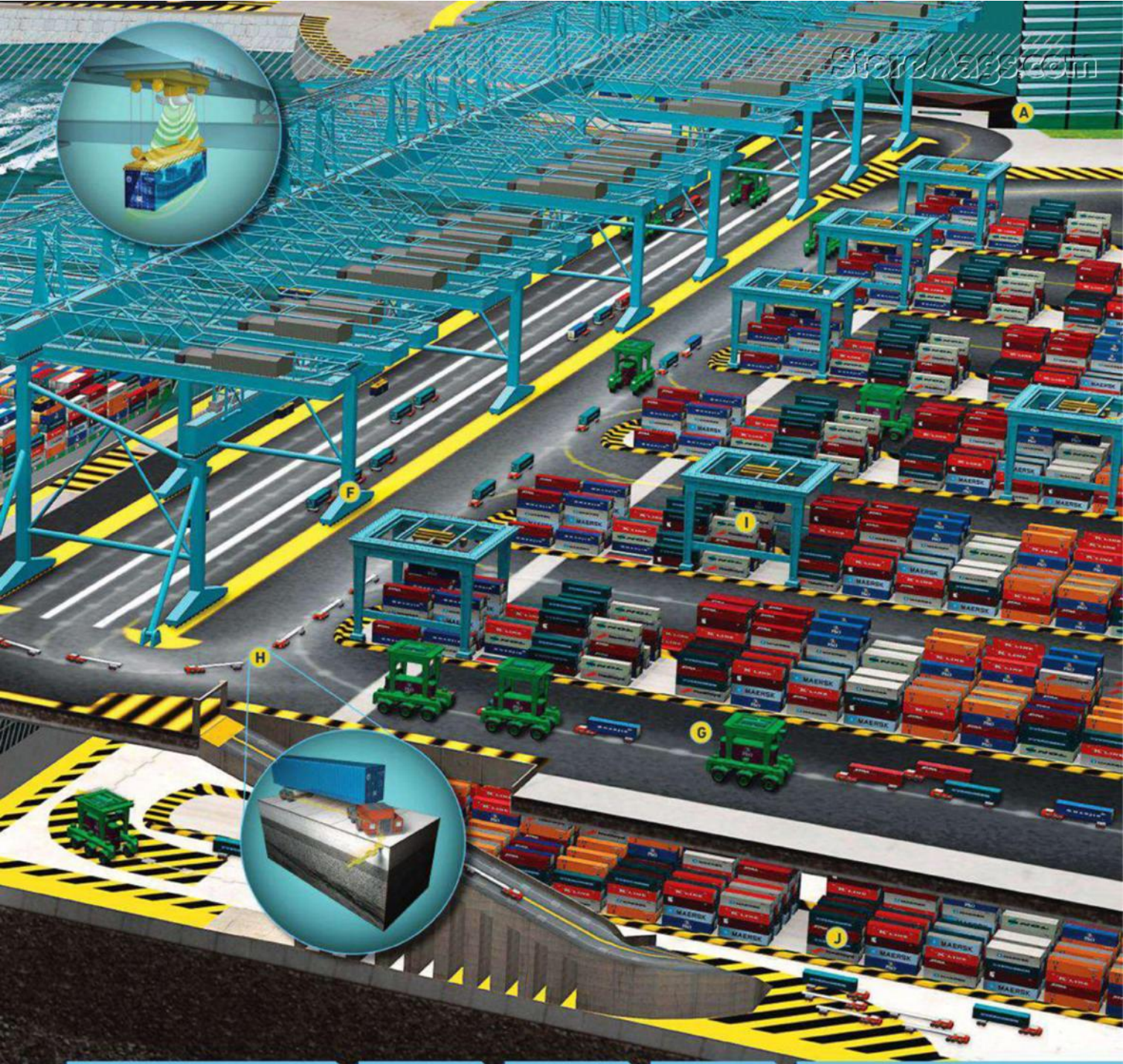
Docked ships power down and plug into outlets (E) from which they can draw energy for communications and other systems. Providing shoreside power to a cargo vessel for one day reduces emissions and improves air quality near the port.

Ship unloaders

Slimmed-down horizontal container cranes (F) quickly pluck containers off the ship and place them onto robotic carts below. Instead of the bulky legs typical of conventional cranes, FastNet cranes, from Dutch company APM Terminals, have wheeled pillars that rearrange themselves beneath the elevated girders to avoid ground vehicles—all of which will double current loading and unloading speeds.

Container carts

Unmanned trucks, such as the new AutoShuttle (G) created by Finnish company Cargotec, pick up containers and, using RFID and optical character recognition, instantly retrieve identifying data and instructions on where to move them.



Electromagnetic floors

Electromagnets (H) embedded in terminal roadways wirelessly transfer energy to receiver coils on the undersides of electric port vehicles (today they are diesel or diesel-electric hybrids). Container carts, stackers and other mobile machinery pick up power as they carry out their duties and store it in either onboard battery packs or power-dense, quick-charging supercapacitors. Nebraska-based Conductix Wampfler and Swiss transport company Numexia are both already manufacturing energy-transfer systems that could be adapted for ports.

Stacking cranes

Three-story-tall autonomous, energy-efficient maglev cranes (I) rearrange containers into seven-box-high stacks in the container yard. In the rail yard, they load containers onto the beds of waiting semi trucks or freight cars.

Storage silos

Secure, climate-controlled underground storage facilities (J) rely on automated tracking systems that communicate directly with container computers and the port-manager program to arrange and locate cargo.

Cargo screeners

A compact particle accelerator (K) beams high-energy photons through containers. High-resolution detectors measure how the photons scatter or get absorbed to determine the composition and shape of the objects inside.

Port patrollers

A fleet of autonomous submarines (L) carries out around-the-clock surveillance, using sonar, radar and video to detect intruders and inspect port infrastructure, while armed autonomous speedboats (M) patrol the surface. Unmanned surface vehicles (USVs) are already securing ports in the Middle East. But marine-control researchers at the Norwegian University of Science and Technology are working on smarter USVs that can make tactical decisions, work in formation, and autonomously coordinate with any other land, air or sea robots.

**BUILD YOUR OWN
MAKE-ANYTHING MACHINE** P.82

STEM-CELL TOURISM

Adventures at the Fringes of Experimental Medicine P.64

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THE FUTURE OF THE ENVIRONMENT

ECOTOPIA

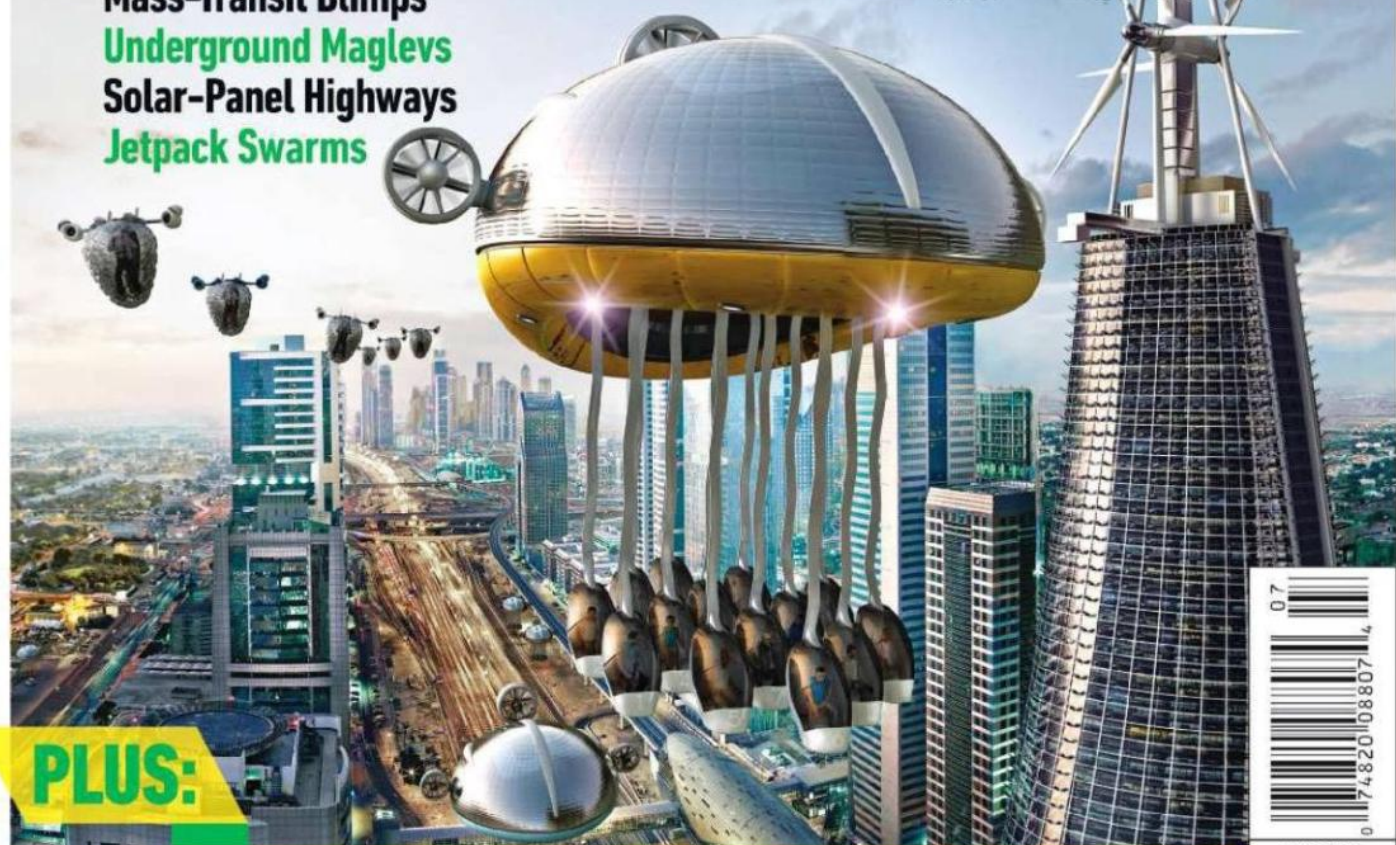
Visionary Plans to Create a Sustainable Urban Paradise P.46

Mass-Transit Blimps
Underground Maglevs
Solar-Panel Highways
Jetpack Swarms

28
Hot Products



Your Personal
3-D Camcorder P.19



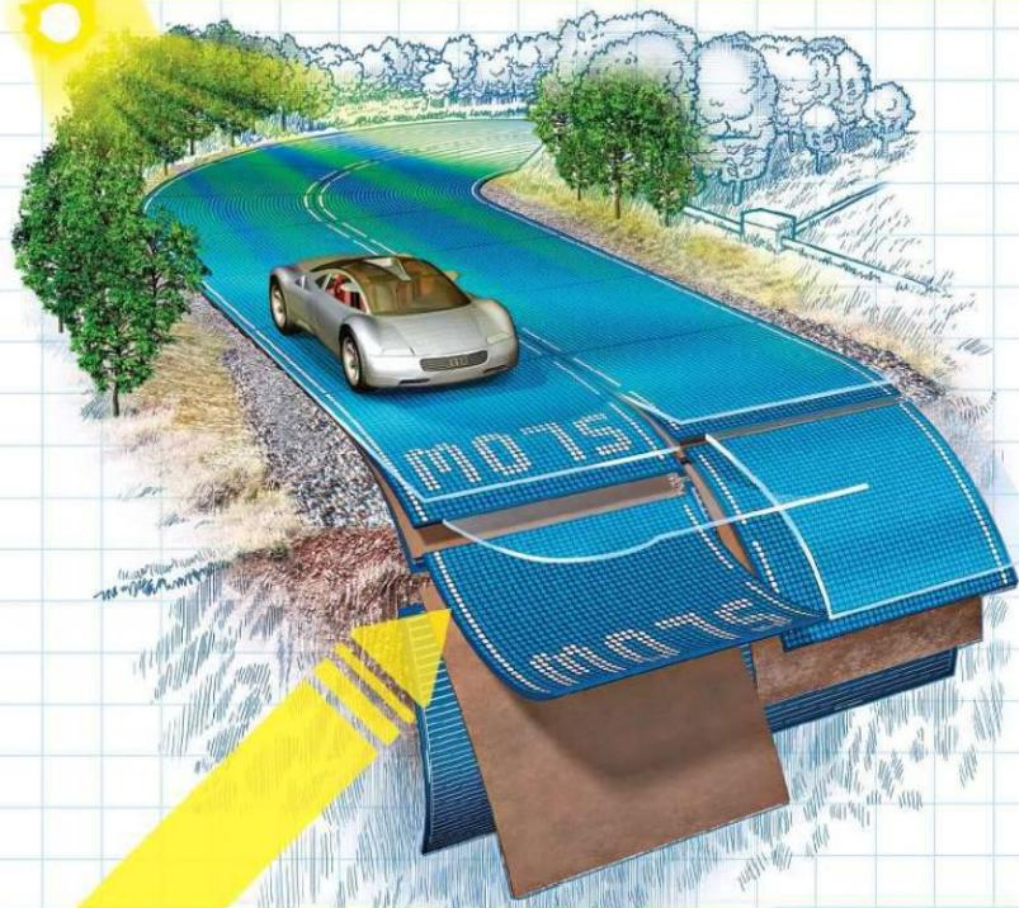
PLUS:

How Diapers Could Transform Deserts into Lush Edens P.49



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THE SOLAR ROADRUNNER

Highways baking in the hot sun are wasted energy.
Scott Brusaw's solution? Make them out of solar panels

The road ahead is paved with photovoltaics. That's how Scott Brusaw sees it, anyway. His company, Solar Roadways, is embedding PV cells and LED lights into panels engineered to withstand the forces of traffic. The lights would allow for "smart" roadways and parking lots with changeable signage, while the cells would generate enough energy to power businesses, cities and, eventually, the entire country.

Each 12-by-12-foot Solar Roadway panel would produce about 7,600 watt-hours a day, based on an average of four hours of sunlight. At that rate, a one-mile stretch of four-lane highway could power about 500 homes. "If we could ever replace all the roads in the U.S., then, yeah, we would produce more electricity than we use as a nation," says Brusaw, an electrical engineer who completed his first prototype panel in

February with funding from the U.S. Department of Transportation.

Brusaw's goal is to get the cost per panel under \$10,000. That's roughly three times the cost of asphalt. But he wants to make panels that last three times longer than asphalt roads, which have to be resurfaced every 10 years in many places. "Then the cost is about the same," he says. "But that's just a break-even. We're also generating electricity."

The key to commercial viability will be the panels' glass. It must be textured for traction, embedded with heating elements for melting away ice and snow, and able to survive years of traffic. "The toughest is going to be that fast lane on the highway," Brusaw says, "where you've got a 40-ton truck, maybe with snow chains. It will have to be able to withstand all that." At the same time, it has to be self-cleaning if sunlight is to reach the PV cells; Brusaw points to experimental hydrophilic glass that uses sunlight to break down organic dirt, and rainwater to wash it away without streaking.

Next up for Solar Roadways will be qualifying for Phase II funding, a two-year, \$750,000 deal to develop a commercial plan for the panels. At the end of those two years, Brusaw would like to be ready for testing in parking lots, which he sees as the perfect proving grounds for the lights and the power-generation system. Directional arrows and parking lines could be reconfigured to deal with busy times, and the electricity generated could feed adjacent businesses. "I talked to the guy in charge of power for Wal-Mart," Brusaw says. "Superstores are roughly 200,000 square feet, and parking lots are about four times that. I crunched the numbers for an 800,000-square-foot lot and told him how much power it could generate even if it was completely full of cars. It was 10 times the power they use."

Brusaw wants to start smaller, though—on the scale of, say, a fast-food restaurant. A McDonald's retrofitted with a solar parking lot could take itself largely or entirely off the grid or become a site for recharging electric vehicles (while the owners stopped inside for food, naturally). "Even the best electric cars have a range of about three hours," he explains. "But if all I have to do is find a McDonald's, I could drive from Idaho to the southern tip of Florida." Improbable? Yes. But "Billions of watts served" would be a cool new tagline.—J.B.

KEVIN HAND

THE LAZY ENVIRONMENTALIST: NO-SWEAT TIPS FOR GOING GREEN

Get Paid to Save Money on Your Utility Bill

The My Emissions Exchange Web site challenges homeowners to conserve energy and calculates the equivalent amount of carbon emissions avoided. Reduce your electric bill by about \$200, for instance, and you'll generate a carbon credit, which is equal to roughly one ton of carbon saved. My Emissions Exchange sells the credit on your behalf on the voluntary carbon market at a going rate of between \$10 and \$25, taking a 20 percent cut on all sales. The rest goes into your PayPal account. MyEmissionsExchange.com

Josh Dorfman is the author of *The Lazy Environmentalist: Your Guide to Easy, Stylish Green Living*.

THE URBAN REMODELER

It would be easy to dismiss Mitchell Joachim's fantastical vision for ecological supercities, with their flocks of jetpacks and mass-transit blimps that look like flying monster jellyfish, as science fiction—if he wasn't actually building them

Architect Mitchell Joachim points out, frequently and without prompting, that his futuristic proposals are always based on existing technologies. No wonder he feels the need to say it. Consider some of his ideas: jetpacks tethered together in swarms, houses grown from living trees, low-altitude blimps prowling New York City with chairs hanging below them for pedestrians to hop on and off (24/7 ski lifts on Broadway!), and WALL-E-like machines that erect buildings and bridges from recycled waste.

For Joachim, a 39-year-old professor of architecture at New York University, with graduate degrees from MIT, Harvard and Columbia, these concepts aren't Hollywood fluff but designs that could come to life today. Take his concept for waste-building machines, which he calls Rapid Re(f)use. Instead of the cubes of cardboard, plastic or steel that current recycling balers produce, Joachim's robots would grind and compress waste into I-beams, cruciform columns or even furniture components. The structures would be pressed or melted into shape or wrapped with metal bands, which is what recycling plants do now. All that would change is the shape—like switching the mold on a Play-Doh press, but on an industrial scale. "We could do it yesterday," Joachim insists.

His vision falls under the banner of Terreform ONE, a nonprofit design collective that Joachim co-founded to explore sustainable, fully integrated urban planning. If the same people who design the roads also design the cars, he says, and the same people who create the suburbs also plan for ways to feed and transport residents, our cities will become healthier, friendlier and more sustainable.

The group imagines how future cities might best serve their citizens on a large scale and then experiments with the small-scale materials and designs that it would take to make it happen. To this end, Terreform ONE hosts TerreFarm, an annual summer gathering

of architects and scientists who develop new urban farming techniques. For several weeks this summer, TerreFarm will convert a Brooklyn rooftop into a testbed for modular growing methods, designs for maximizing available sunlight, and ultra-lightweight soil mixes essential for rooftop gardens. They will also build full wall sections of Joachim's Fab Tree Hab, his proposal to create "living" homes by grafting trees together around scaffolds and growing them on-site.

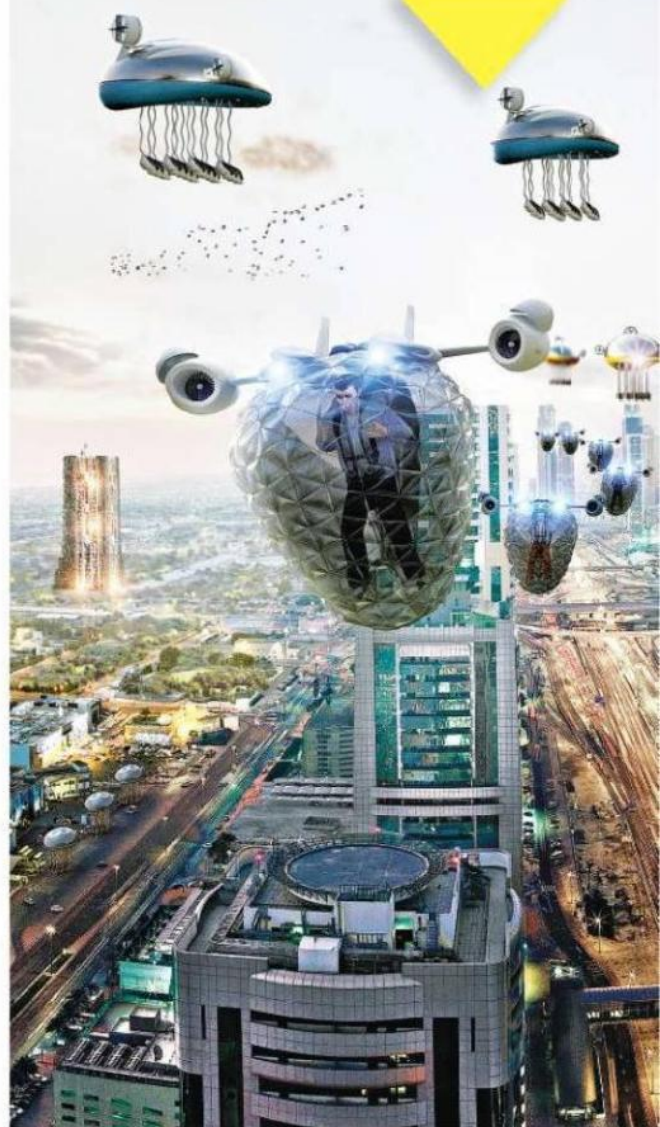
Joachim's other plans tend to focus on mobility, since transportation both shapes and is shaped by urban design. In his vision, individual cars would be replaced by car-share systems that function like luggage carts at an airport. Pay, step into a smart car that communicates with the city grid, drive to your destination, and leave the car there. The cars would have soft, springy exteriors, inflatable protective bladders and transparent foil, which would enable them to bump together as they traveled in flocks. "The idea of sharp metal boxes is just done," Joachim says. "We design cars with the principle that no one would ever die in a car accident again."

Joachim's blimps would move like trolley cars. Their routes would be set by funicular cables, and they would float slowly enough that pedestrians would be able to hop on and off hanging chairs dangling above the ground. Unlike a trolley car, though, the blimps would also be able to cross rivers, gorges and other geographic features without bridges.

His jetpack designs are not the retro-futuristic rocket belts of the 1960s but more like the lightweight ducted-fan jetpacks scheduled to go on sale later this year from Martin Aircraft Company. For efficient commuting, Joachim's jetpacks—soft and flexible like his cars—would be towed in flocks by a plane or blimp. "Bump and glide," as Joachim describes it. From there, individuals could break off, power up, and fly safely to their homes or offices—like subways

in the sky. "It's hard to find people who don't want to be moving around in jetpacks in 20 years," he says. "As an architect, then, I'm responsible for thinking about what the implication of the jetpack is on the future city."

Joachim's willingness to forgo lucrative commercial projects in favor of running a nonprofit dedicated to the reimagining of a future he won't even be around for is, say his colleagues, exactly what makes him so vital. Traditionally, "cities are built incrementally by real-estate interests," says Richard Sommer,



the dean of architecture at the University of Toronto. "What's important about Mitchell's work is that he [takes] a visionary approach."

The vision part involves looking 150 years down the road and planning for how cities will have to operate within the environment if civilization is to endure. Even if the technologies exist today, Joachim says, no one can change the city tomorrow. "Once we heard about cellphones, it was about seven years before we started dropping the landline," he says. "It took about 15 years before you could buy a hybrid

car on every lot. It takes around 40 years to produce a large shift in the way buildings are constructed. Entire cities? It's 100, 150 years."

In the meantime, Joachim is busy producing the stuff that will get us there,

whether it's growing living walls, planting organic lettuce on urban rooftops, or making sure that when your grandkids are ready for their first jetpacks, their cities will be too.

—JOHN BRADLEY

"AS AN ARCHITECT, I'M RESPONSIBLE FOR THINKING ABOUT WHAT THE IMPLICATION OF THE JETPACK IS ON THE FUTURE CITY."

NICK KALOTERAKIS



THE SAND SCULPTOR

With the Sahara desert rapidly encroaching on livestock-nourishing grassland, architect Magnus Larsson proposes a 3,728-mile-long barrier wall—built by bacteria

Could a student architecture project help save millions of Africans from the relentless advance of the Sahara desert, a phenomenon that's fueling drought, starvation and poverty? There's one that has people talking. Borrowing from an experimental solution for firming up building foundations in earthquake-prone areas, Swedish architect Magnus Larsson, 34, has proposed solidifying the sand dunes at the leading edge of the Sahara to create a habitable 3,728-mile-long desert-blocking wall.

Outlandish? Yes and no. In terms of science, the method is proven. Researchers at the University of California at Davis have been investigating the technique—which involves injecting the bacterium *Bacillus pasteurii* into the soil in a calcium-rich, alkaline mix—as a means to stabilize the ground in earthquake-prone regions. In the lab, it can solidify 32 square feet of soil in a matter of hours, although they estimate that it would take up to a few weeks for large-scale solidification.

In terms of geographic breadth, Larsson's proposal, which he submitted as a final-year project while studying at London's Architectural Association, is roughly on scale with the Green Wall of the Sahara, a 23-nation initiative already under way, to contain the spreading desert with a nine-mile-thick barrier of trees extending along the same stretch that Larsson is eyeing. In fact, Larsson sees his project as supporting the Green Wall, literally. His hardened sand wall—up to 1,000 feet deep in some places—would

KEVIN HAND

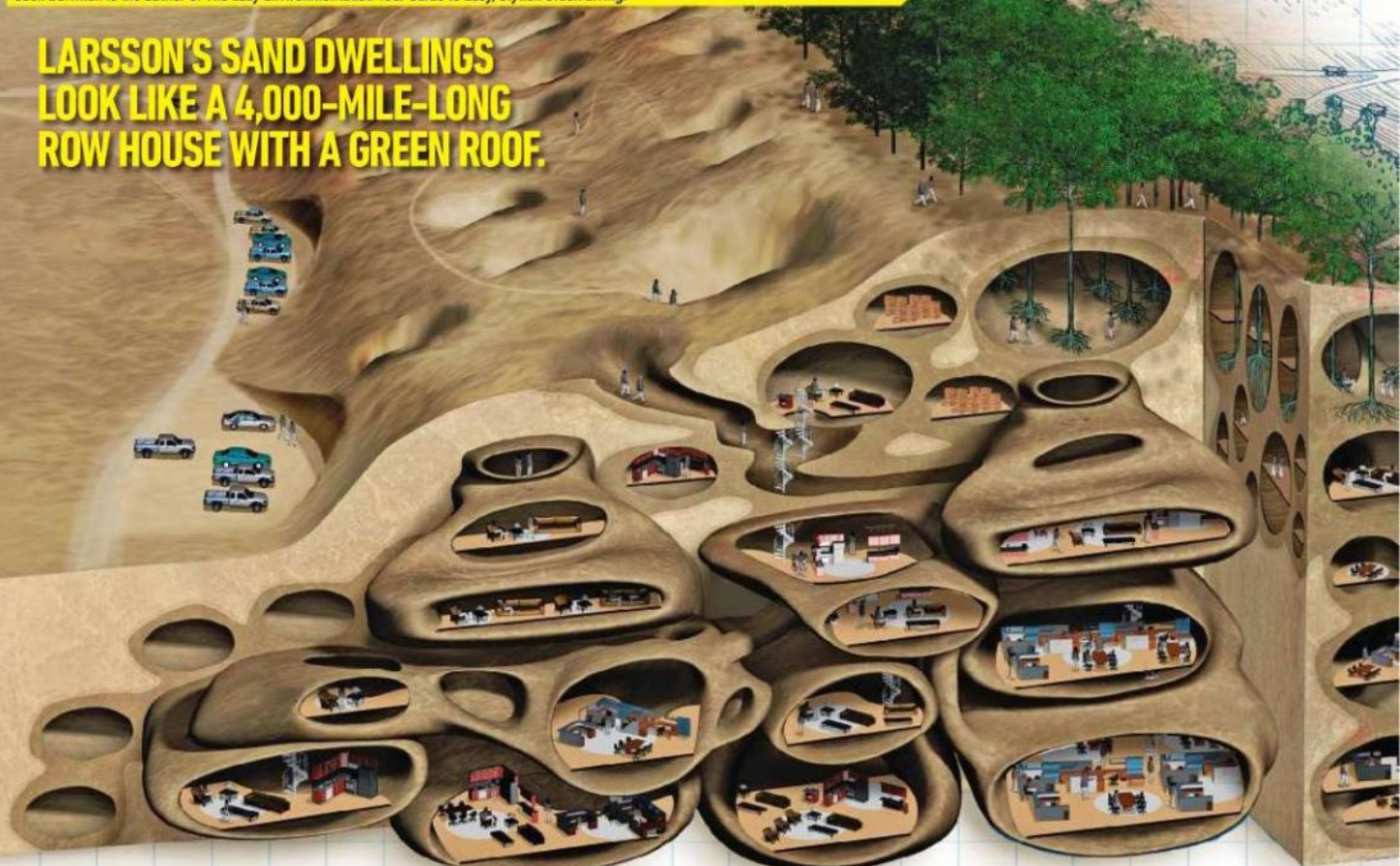
THE LAZY ENVIRONMENTALIST: NO-SWEAT TIPS FOR GOING GREEN

Turn Off Energy Hogs from Anywhere—Without Getting Up

For those foggy mornings when you leave the house without turning off the TV, Picowatt plugs let you remotely power down the tube, along with the rest of your electronics and lights. Plug Wi-Fi-enabled transmitters into your wall sockets and connect your electronics. The transmitters relay real-time energy usage and cost data to a personalized Picowatt Web page or to your phone. From there, it's just a few clicks to manage your home's energy consumption. \$80 per plug; tenrehte.com

Josh Dorfman is the author of *The Lazy Environmentalist: Your Guide to Easy, Stylish Green Living*.

**LARSSON'S SAND DWELLINGS
LOOK LIKE A 4,000-MILE-LONG
ROW HOUSE WITH A GREEN ROOF.**



provide a more stable base for the trees, with full-scale homes carved out of the dunes. In his drawings, the dwellings look like millions of row houses with green roofs keeping the desert at bay. Solidification, Larsson maintains, would pose few risks to the environment or human health, since it relies on harmless microbes naturally present in marshes and wetlands. The U.C. Davis method simply spurs the microbes to excrete extra calcium carbonate, bonding the sand together tightly like cement.

For now, Larsson is seeking funding for large-scale tests to demonstrate whether and how his method would work. Even if it does, he admits, the implementation would be financially daunting. "The cost would be a ridiculous figure," he says. "It's like asking what it would cost to build the Great Wall of China today. It wouldn't be cheap. But then again, any project attempting to tackle such an ambitious challenge is going to be expensive." —J.B.



DIAPER FARMER

Willem van Cotthem's super-soil harnesses the power of Pampers to turn dirt into lush gardens



When asked to imagine the Earth in 2040, many scientists describe a grim scenario, a landscape so bare and dry, it's almost uninhabitable. But that's not what Willem van Cotthem sees. "It will be a green world," says van Cotthem, a Belgian scientist turned social entrepreneur. "Tropical fruit can grow wherever it's warm." You still need water, but not much. A brief splash of rain every once in a while is enough. And voilà—from sandy soil, lush gardens grow.

The secret is hydrogels, powerfully absorbent polymers that can suck up hundreds of times their weight in water. Hydrogels have many applications today, from food processing to mopping up oil spills, but they are most familiar as the magic ingredient in disposable diapers. The difference with agricultural hydrogels is that they don't just trap moisture; they let it go again, very slowly, almost like time-release medication, into the root system of plants. That continuity of moisture is what brittle landscapes like deserts need to become fertile again. Water activates a mineralization process, setting free nutrients in the soil so that life can grow.

But water alone won't make gardens flourish in sand. So van Cotthem, an honorary professor of botany at Ghent University in Belgium who has helmed several international scientific panels studying desertification, invented a "soil conditioner" called Terracottem. It's an 8- to 12-inch layer of dirt impregnated with hydrogels, along with organic agents that nourish the natural bacteria in the soil.

Van Cotthem's early experiments with his soil are now literally bearing fruit on every continent except Antarctica. Where Terracottem sits, barren plots of land are now fertile, and have already changed lives. In 2005, UNICEF invited van Cotthem to oversee the construction of "family gardens" in the Sahawari refugee camps in Algeria. Since 1975, thousands of Africans in the camps have lived in tents and shacks, dependent on the World Food Program to provide them with dry and canned goods—a diet that left

them vulnerable to disease. Today more than 2,000 pocket gardens there provide healthy food.

If this technology is so miraculous, you might wonder, why wasn't it developed earlier? After all, disposable diapers have been around since the 1940s. Until only recently, though, hydrogels were toxic, and skeptics doubted that they could ever be made safe for consumption. There was no bigger skeptic than van Cotthem himself—so much so that the day a research engineer from a German diaper company walked into his lab and told him he'd cracked the nut, van Cotthem said to his face, "I don't believe you."

"OK," the engineer said. And he took out a spoon and ate the hydrogel. Van Cotthem was shocked. Then he said to his visitor, "Please come back in a couple of months so that I know you're still alive." Meanwhile, van Cotthem tested the samples, got promising results, and began researching the agricultural uses of hundreds of kinds of hydrogels. When the engineer returned alive, van Cotthem was convinced.

But new soil isn't enough—people still need something to grow in it. Realizing that half the world routinely throws out seeds that the other half needs, van Cotthem also launched a nonprofit organization called Seeds for Food that asks people to mail in their unwanted seeds. "My office right now is full of pumpkin seeds people sent in after Halloween," he says.

Scientists are exploring different uses for hydrogels. Enhanced soils, they believe, could be the key to farms in space. The recipe is simple: a few drops of water and glass-like marbles to provide a kind of scaffolding for roots in the soil. "Suddenly," van Cotthem explains, "you have a rich soil that can support almost anything." But his sights are set firmly on this star system. "I do see the possibility of achieving wonderful things in space," he says. "But let us first solve the problems here on Earth, starting with offering everyone the chance to produce their own food. And we are certainly in a position to do so."

—BRUCE GRIERSON

THE BIG GUN

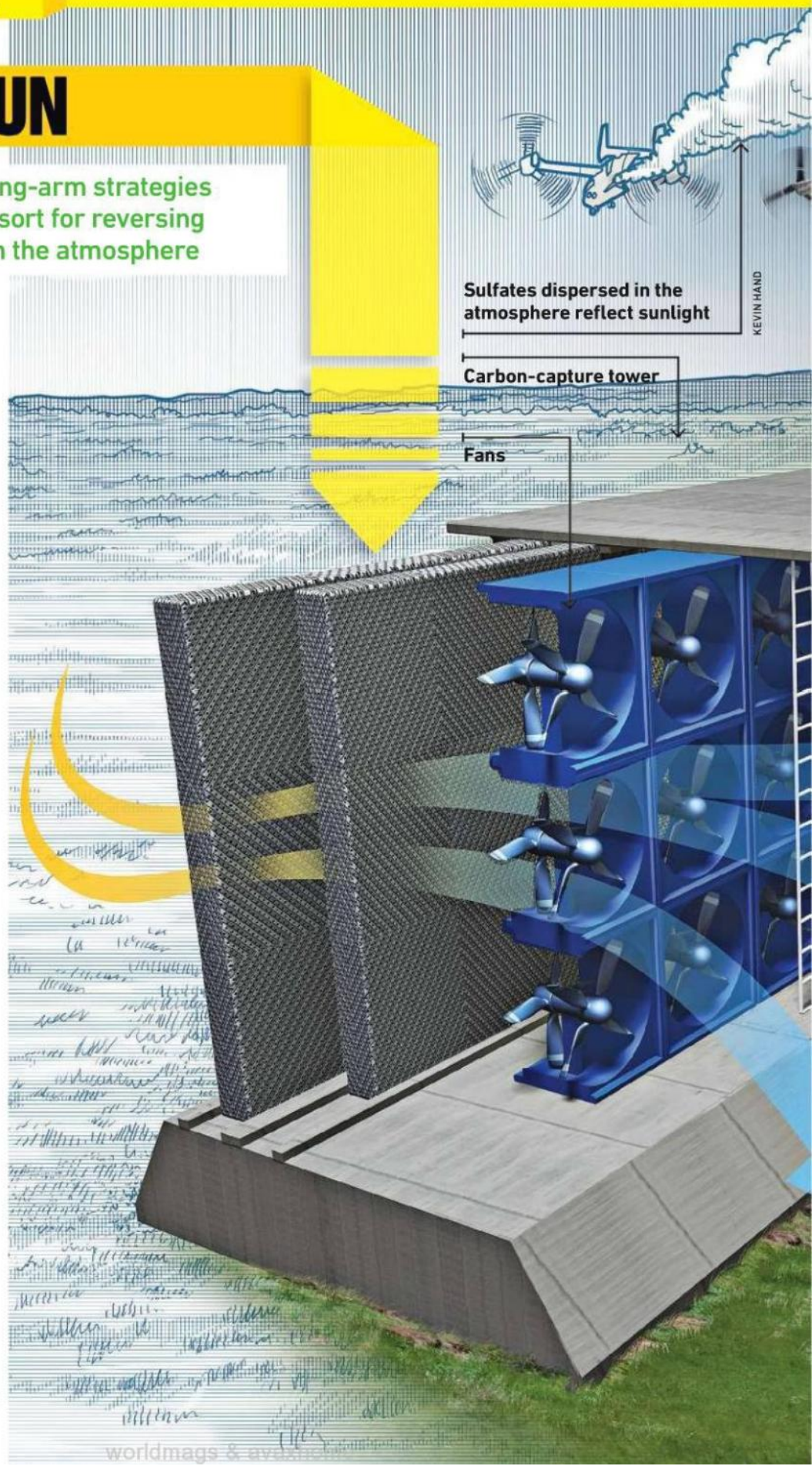
David Keith believes strong-arm strategies could soon be our last resort for reversing record levels of carbon in the atmosphere

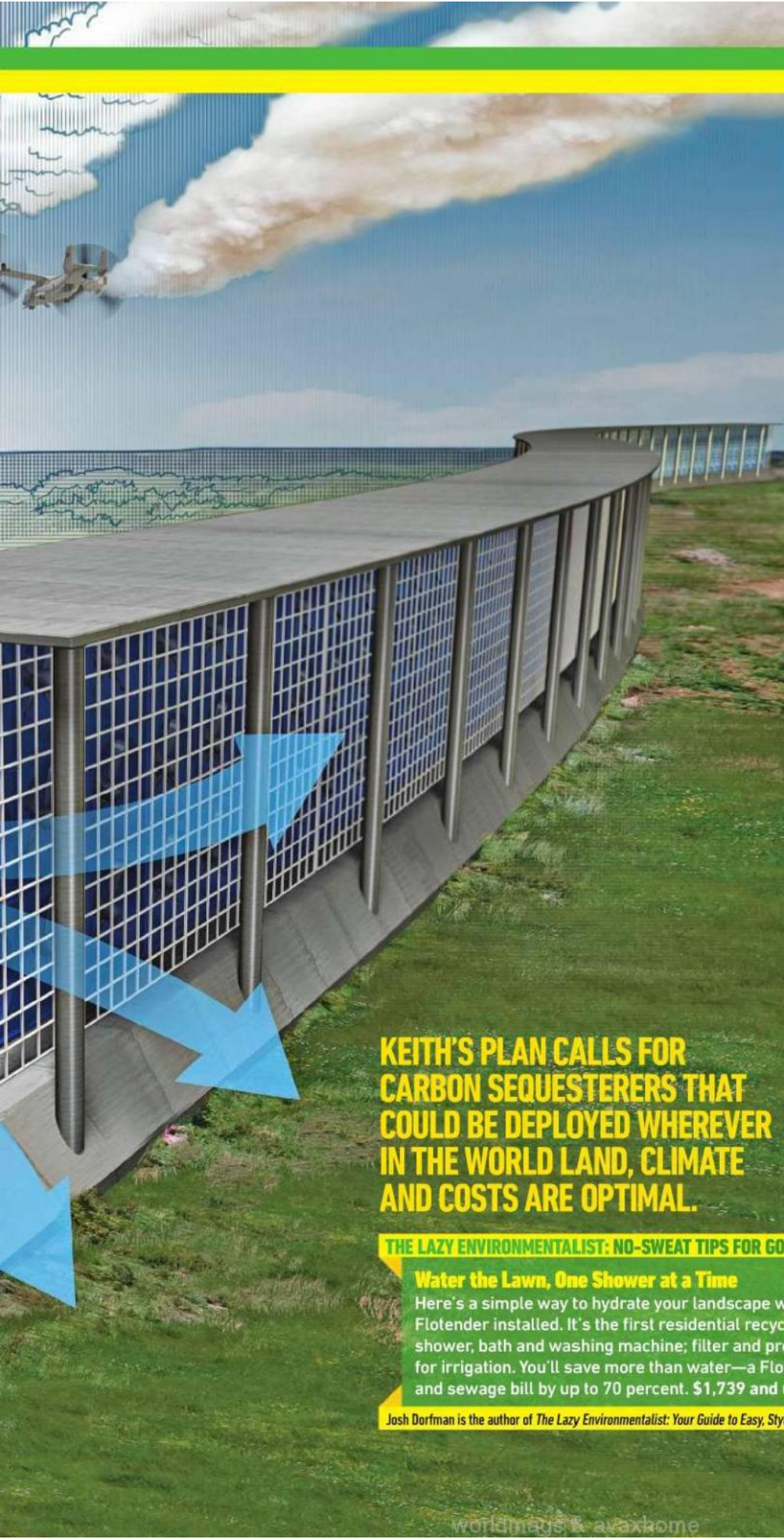
In the 1992 film *Unforgiven*, Clint Eastwood spends most of the movie slowly and methodically avoiding violent confrontation with the bad guys before finally turning things around with a bloody burst of gunslinging. That's something like the approach of Canadian physicist and environmental scientist David Keith. Except that his villain is climate change, and while he's still doing everything he can to avoid a fight, Keith is also stockpiling ammo.

"If we do the job we should be doing on cutting emissions, and we are lucky, we won't need geoengineering," says Keith, a professor at the University of Calgary whose start-up company, Carbon Engineering, is developing commercial-scale devices to capture atmospheric carbon dioxide. That's the slow and methodical. "But if we can't control atmospheric CO₂ well enough, then we might want to do the solar stuff." That's the gunfight.

For several years now, Keith, who has served as a member of Canada's blue-ribbon panel on sustainable energy technology and as a member of U.S. National Academy of Sciences committees, has been the leading voice in the call for serious research into geoengineered schemes for cooling the planet. The most common example would be to scatter sulfates in the stratosphere to reflect sunlight away from the planet. The cooling would be immediate and global. We know this, Keith says, because it's happened before. When Mt. Pinatubo erupted in the Philippines in 1991, the resulting plume of sulfuric ash cooled the planet by about 1°F for a year. Carbon dioxide remains in the atmosphere for centuries, and even the most optimistic proposals for CO₂ sequestration would take decades to have an effect. Should we find ourselves faced with an immediate environmental emergency—a shifting Gulf Stream or an impending collapse of the Arctic ice sheets—effective "sunlight mediation" could theoretically be a quick retreat from the edge.

The immediate problems with this, however, are twofold. First, there's an obvious moral hurdle. Most people reflexively reject notions





KEITH'S PLAN CALLS FOR CARBON SEQUESTERERS THAT COULD BE DEPLOYED WHEREVER IN THE WORLD LAND, CLIMATE AND COSTS ARE OPTIMAL.

of geoengineering for fear that they may cause more harm than good, and undermine efforts to reduce carbon emissions. The other drawback is that the method would be cheap and easy enough that even a rogue nation could pull it off, which leaves open the very real possibility of unilateral action with global consequences.

The real hope is to refine geoengineering methods and develop standards while simultaneously working toward a future in which they would never have to be used. That's where Keith's carbon-sequestration technology comes in. Most carbon-capture systems propose sequestering CO_2 from large facilities such as power plants. Keith's plan, however, is more mobile, calling for towers that could be deployed wherever in the world land, climate, and labor costs are optimal.

These carbon suckers would employ fans to move air through a solution of sodium hydroxide, which absorbs the CO_2 . Inside, lime bonds with the carbon dioxide to form solid calcium carbonate. The reaction releases the sodium hydroxide for reuse in the first step, while the CO_2 could be stored in underground reservoirs that once housed oil and gas or be recycled into gasoline [see page 53].

Keith has proven this process with a test tower 20 feet tall and four feet wide that can capture two tons of CO_2 per square foot annually (roughly equivalent to the yearly output of one American) using less than 100 kilowatt-hours of electricity per ton. His company expects to spend about \$5 million over the next three years refining the technology and investigating how best to scale it up—way up. The ultimate goal is for fields of towers some 300 feet long and 60 feet tall, scrubbing up to 1.1 million tons of carbon a year.

Keith admits that his carbon scrubber is no silver bullet. "We have patents and new ideas," he says, "but the thing you have to get right is cutting emissions. Unless you do that, CO_2 removal will be irrelevant." And if we don't do it quickly enough, the guns may have to come out.—J.B.

THE LAZY ENVIRONMENTALIST: NO-SWEAT TIPS FOR GOING GREEN

Water the Lawn, One Shower at a Time

Here's a simple way to hydrate your landscape without lifting a finger: Have a Flotender installed. It's the first residential recycling system to capture water from the shower, bath and washing machine; filter and pressurize it; and channel it to the yard for irrigation. You'll save more than water—a Flotender can reduce your annual water and sewage bill by up to 70 percent. \$1,739 and up; flotender.com

Josh Dorfman is the author of *The Lazy Environmentalist: Your Guide to Easy, Stylish Green Living*.

PLANS FOR

Architects and engineers are already prepared for the future. These ingenious conceptual structures scrub away pollution, heat themselves, and generate power for us all

BY SUZANNE LABARRE

THE LIFE AQUATIC

PHYSALIA IS HALF-BOAT, half-building, and all green. This mammoth aluminum concept by Belgian architect Vincent Callebaut is meant to travel Europe's rivers, making filthy water drinkable. At the same time, the ship generates more energy than it uses.

A coat of titanium dioxide paint brushed onto the silvery

▲ A museum, nightclub and filtration system, Physalia uses its hull and rooftop plants to scrub away pollution.

shell will neutralize pollution by absorbing ultraviolet rays, enabling a chemical reaction that decomposes organic and inorganic toxins. (It's the same technology used in certain high-tech concrete that breaks down airborne particulates.) As the vessel whips along, purifying waterways, it can draw on both solar and hydro

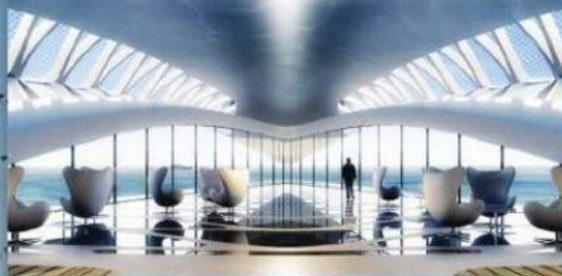
power. Turbines under the hull transform water movement into electricity, and rooftop photovoltaic cells harness energy from the sun. The roof doubles as a nursery, whose carefully selected plants help filter river gunk, whether from the Thames, Rhine or Euphrates.

But Physalia isn't just designed to be a working ship. The vessel

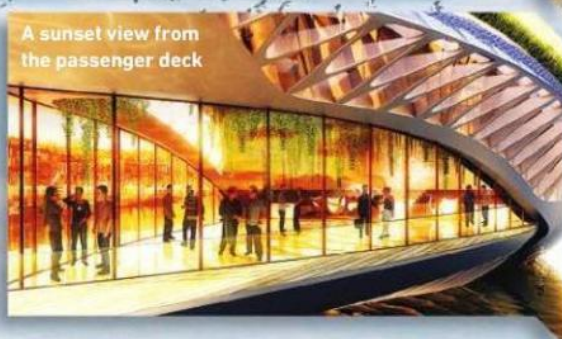
TOMORROW



The interior of the ship's water garden



A sunset view from the passenger deck



The steel hull is plated with titanium-dioxide-coated aluminum.



Hydroturbines under the hull generate electricity.



will also be a floating museum of sorts. Scientists who study aquatic ecosystems can hole up in the dedicated "Earth garden" lab, and tourists can visit temporary exhibits in a "water garden" or settle into a submerged lounge that could easily pass for a London nightclub. Callebaut, 33, dreamed up the idea after last year's United

Nations Climate Change Conference in Copenhagen shone a long-overdue spotlight on global water issues. He has some lofty terms for his project: It's a "nomadic hydrodynamic laboratory," a "fragment of living earth," and a "floating agora" on a "geopolitical scale." Others might just call it a cool idea.

A LIVE-IN POWER PLANT

AT FIRST GLANCE, the plans for the 10MW Tower have all the trappings of pre-crash Dubai: the improbable height, the flashy facade, the swagger of a newbie in a crowded skyline. On closer inspection, however, it's an eco-machine. The A-shaped, 1,969-foot concept skyscraper is designed to turn out as much as 10 times the energy it needs, enough to power up to 4,000 nearby homes.

Three separate systems make it work. First, a five-megawatt wind turbine in the hollow of the "A" generates energy in the powerful and unpredictable desert gusts. Second, mirrors dot the slanted, south-facing facade, beaming light to a molten-salt-filled collector that hangs off the building like an ultra-tall street lamp. Cooked to 932°F, the liquefied salt transfers heat to a convection loop that runs a three-megawatt steam turbine. Finally, a two-megawatt solar updraft tower produces additional energy in clear weather. Sunlight warms air in a two-foot-wide gap that runs the length of the southern face. The airflow from rising heat powers an internal wind turbine.

If it were built (at an estimated cost of \$400 million), 10MW could pay off its energy debt in 20 years. Extra juice feeds the municipal grid, and other sources in the area would adjust for the tower's output. The building could house offices or residences or both, says designer Robert Ferry, 35, who helms the Dubai architecture firm Studied Impact with his wife, Elizabeth Monoian. The pair became interested in energy-generating skyscrapers on moving to the United Arab Emirates, where there are superstructures in spades but few that are any greener than their brochures. With the 10MW Tower, they hope to someday create a power plant you can live in. It may sound fantastic, but, Ferry says, "it's only a matter of time before something like this is built."

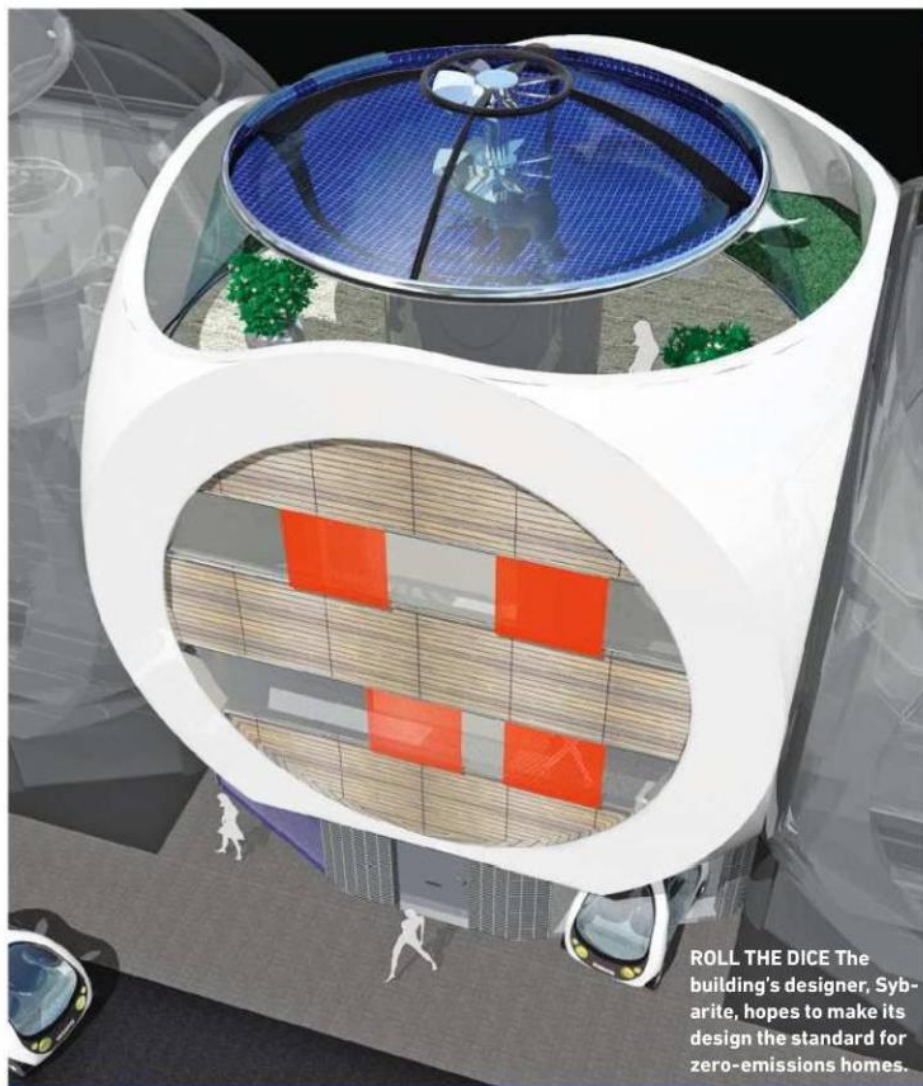
COURTESY ROBERT FERRY/STUDIED IMPACT DESIGN; PRECEDING PAGES: COURTESY VINCENT CALLEBAUT ARCHITECTURES



REVOLUTIONARY A five-megawatt turbine contributes to the building's annual output of 20,000 megawatt-hours.



REFLECTIVE The facade directs light to a power-producing salt-cooker.



ROLL THE DICE The building's designer, Sybarite, hopes to make its design the standard for zero-emissions homes.

GREEN GAMBLE

THE DICE HOUSE looks like part of a Monopoly set, but the design has real-world ambitions. The 30-by-30-by-30-foot concept home, designed by the British architecture firm Sybarite, improves on standard building tech to erase its carbon footprint.

The centerpiece is a photovoltaic umbrella dome that collects roughly 90 percent of the house's energy needs. Made of a common plastic, the pillowy dome traps heat like a greenhouse. That hot air warms water in a tank tucked under the roof, turning out a daily average of 80 bath-ready gallons, even on the darkest days of December. At the umbrella's apex, a generator-equipped turbine produces

electricity and, in chilly months, drives heat into the house. Photovoltaic cells studding the 484-square-foot dome floor create additional electricity. Generating an estimated average of 33 kilowatt-hours per day, the house can power itself and charge a Tesla Roadster. And the building, submitted for a carbon-neutral housing competition, manages to stay comfortable year-round without air conditioning. The roof is covered in plants under the dome. Walls made of structural board stabilize temperatures. Windows circumscribed by a big dot—the "one" side of the die—absorb light from the sun-drenched south. And the compact footprint means less space to heat and cool.

FROM LEFT: COURTESY ROBERT FERRY/STUDIED IMPACT DESIGN (2); COURTESY SYBARITE HOUSE

THE TORNADO TRAP

Inside the World's Most Dangerous Weather P.38

SUPERSIZED!

INSTANT EXPERT

Your Crash Course on Memory Drugs, Space Dust and More P.58

POPULAR SCIENCE

THE
FUTURE
NOW

25
Hot Products



Electric-
Vehicle
Home
Charging
Station
P.22

THE FUTURE OF THE HOME

LIFE ON THE EDGE

Extreme Habitats
for a Changing World P.44

PLUS
THE \$50,000
APOCALYPSE-
PROOF
CONDO
P.52

A New Take on Gravity P.29

Can Brain Freeze Kill? P.79

Grow Your Own Spare Lung P.30

\$5.99

OCTOBER 2010



10

0 74820 08807 4

CONTENTS

THIS MONTH'S GUIDE TO INNOVATION AND DISCOVERY



OCTOBER '10
VOLUME 277 #4

FEATURES

THE FUTURE OF THE HOME

44 LIFE ON THE EDGE

Conceptual shelters that will protect us all from rising waters, extreme heat, rampant pollution and overpopulation. **By Suzanne LaBarre**

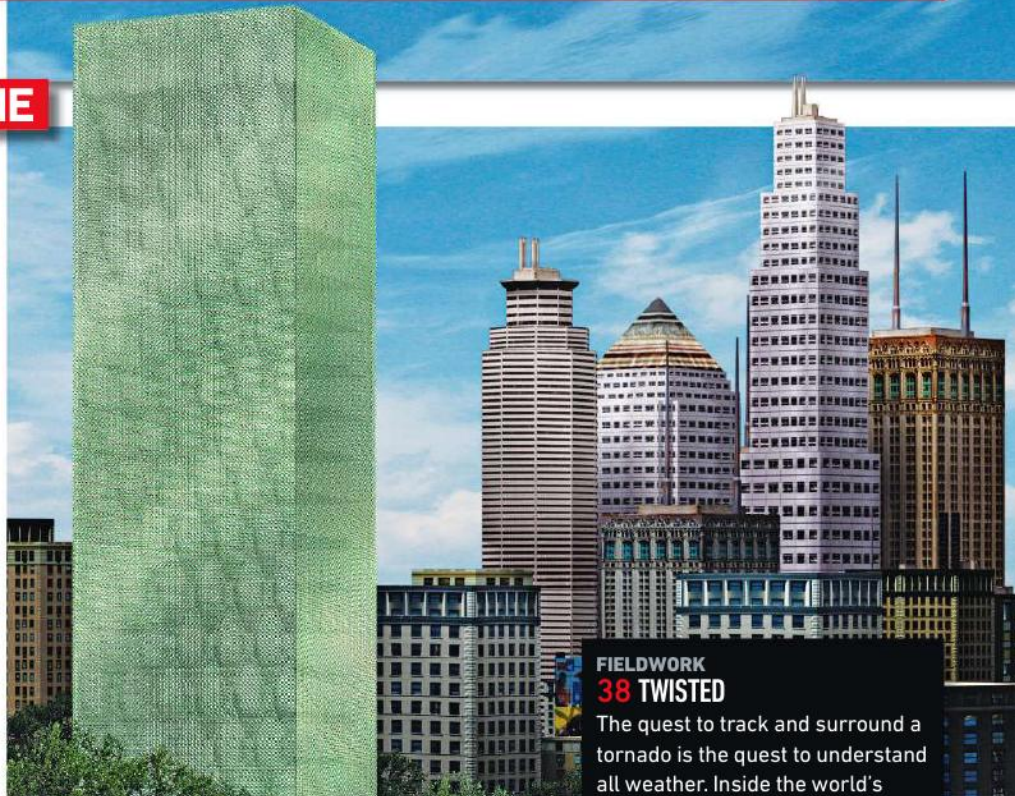
52 CAN THIS HOUSE SAVE YOU FROM THE END OF THE WORLD?

Meet Robert Vicino, doomsday real-estate developer. For \$50,000, he'll sell you a spot in his luxury apocalypse-bunker community. **By Arnie Cooper**

THE GREEN DREAM

56 BRINGING IT ALL HOME

POPULAR SCIENCE's staff photographer has nearly finished building his eco-friendly home. Now he has some hard-won advice for anyone who wants to construct his own. **By John B. Carnett**



FIELDWORK 38 TWISTED

The quest to track and surround a tornado is the quest to understand all weather. Inside the world's most dangerous meteorological experiment. **By Corey Binns**



INSTANT EXPERT

Our annual guide to the science that you need to know now.

58 REBUILT MINDS

New drugs could help scientists understand memory formation and stop age-related memory loss.

By Elizabeth Svoboda

60 EASY FRESHWATER

Desalination techniques are more efficient than ever. Could this process be the answer to our water woes?

By Katharine Gammon

62 UNNATURAL GAS

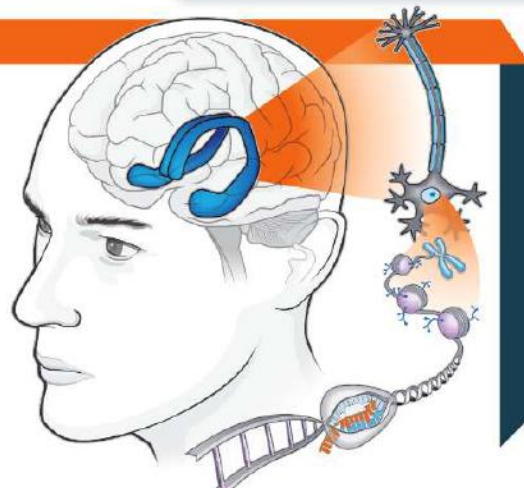
Mining natural gas from shale is cheap but could spoil nearby waters. Here's how to wrest fuel from the rocks.

By Corey Binns

64 DIRTY COSMOS

This map of cosmic dust particles could help astronomers understand how stars and planets form.

By Katie Peek



LIFE ON THE

Four visions for inhabiting a transformed world

PROBLEM

RISE SEAS

SOLUTION: CITY(E)SCAPE

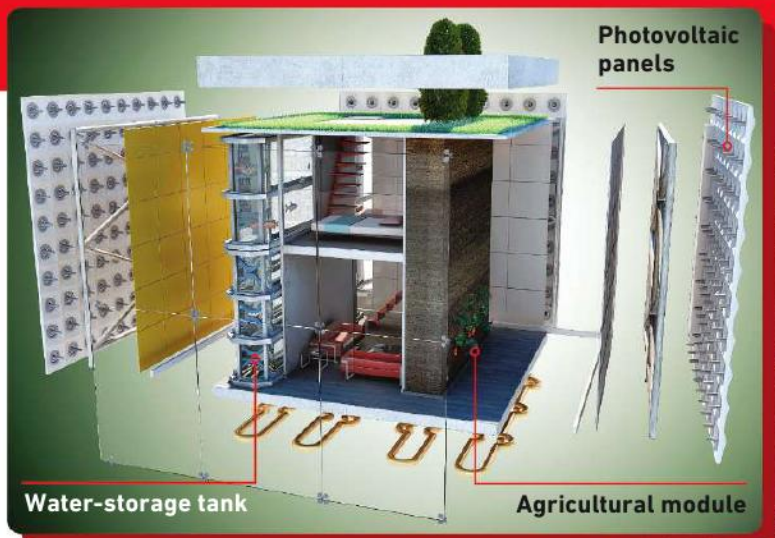
DESIGNERS: MUSTAFA BULGUR AND SINAN GUNAY

Environmental disruptions and technological advances have always influenced where and how people live. Early humans may have left Africa after rapid fluctuations in rainfall destroyed their food supply, and the opening up of the American Southwest occurred roughly in parallel with improvements in air-conditioning technology. In the decades ahead, a warming planet and a booming population will again alter where we live and how we construct our homes.

The most immediately disruptive force could be a rapid rise in sea levels. A coalition of scientists from Denmark, England and Finland predicted last year that by the end of this century, melting ice and thermal expansion will drive up the world's sea levels by more than three feet. It's unclear how many people that would displace, but the damage could be vast—approximately 10 percent of the world's population lives in coastal areas lower than 30 feet above sea level. Land that remains above water will face increasingly frequent storm surges and flooding. The residents of coastal cities could head for higher land, or they could do something distinctly more drastic: They could add a second city above the water.

New York City, for instance, is an archipelago that could lose as much as a fifth of its landmass by 2080. But Mustafa Bulgur and Sinan Gunay, recent graduates of Istanbul Technical University's architecture school, suggest that New Yorkers could make up the lost housing by stringing cables between existing skyscrapers and suspending some 600,000 prefabricated homes among them. By tethering a cable over to structural towers in New York Harbor—it would be possible, they say, to safely house up to 2.5 million people.

The homes themselves, most of them no larger than 800 square feet, would be made from lightweight titanium plates and held together by even lighter-weight carbon nanotubes. Each would be secured to its support cables by powerful electromagnets. It will be hotter in 2080, too, so the northern and southern facades would be covered in



photochromic Plexiglas, which adjusts its translucency according to the strength of the sun. The remaining surfaces would be covered with spiky eight-inch-thick photovoltaic panels. (The spikes, Bulgur says, generate more energy than standard flat panels, because they increase the surface area of the solar collector.) Each unit would contain its own "agricultural module"—a tall column of soil, held together by a silicone net, that would provide fresh fruit and vegetables and also help insulate the house. A tank would store more than 5,000 gallons of freshwater from the citywide supply, which itself would use highly efficient desalination processes to transform the source of the city's trouble into its nourishment.

Other architects have proposed a different approach: homes that require no land at all. Zigloo, a firm in Canada, envisions a narrow underwater skyscraper, deeper than the Empire State Building is tall, that by collecting rain for freshwater and using sun and wind for power would provide a self-sufficient home for 2,000 people (zigloo.ca). Gro Architects in New York proposes harvesting tidal motion to power a network of floating single-family homes (groarc.com). And with the Sub Biosphere 2, architect Phil Pauley imagines a completely submersible habitat for as many as 200 daring aquanauts (philpauley.com).



EDGE

BY SUZANNE LABARRE

WAKE OF THE FLOOD Circa 2080, New Yorkers could live in some 600,000 modular apartments strung along structural cables and held in place by powerful electromagnets. The support cables would be attached to the city's existing skyscrapers.

NICK KALOTERAKIS



THE FUTURE OF THE HOME

MONUMENTAL SQUATTING The architect Stéphane Malka proposes taking over La Grande Arche de la Défense in an overcrowded Paris of the future.



KEVIN HAND

PROBLEM

OVERPOPULATION

SOLUTION: AUTO-DÉFENSE

DESIGNER:

STÉPHANE MALKA

In 2008, for the first time, more than 50 percent of the people on Earth lived in cities. This was good news for the environment; New Yorkers, for example, have a carbon footprint that is a third of that of their suburban and country-dwelling counterparts. But that population shift will also present major challenges. By 2030, some five billion people are expected to live in cities, up from more than 3.3 billion this year—and those cities are expected to be packed. In the 2000 national census, for instance, New York City had a density of 26,400 people per square mile. In 2030 that number is expected to be about 30,000.

New construction will help to alleviate some of the crowding, but Stéphane Malka has another idea: to make better use of the buildings that are already there. Malka, a 35-year-old French architect, proposes taking over La Grande Arche de la Défense, a 361-foot-tall office building and monument to national brotherhood in Paris. It's the perfect building to showcase a system of infill design. In Malka's vision, the arch's hollow belly transforms into a colony of 450 388-square-foot prefab apartments.

Auto-Défense, as he calls the project, relies on basic modular assembly. Housing units would be prefabricated from steel, glass and wood facades stripped from other buildings, then flat-packed and delivered to the arch by truck. On arrival, they would be maneuvered into a structural scaffolding, which itself would

already have been anchored to the interior facade of the arch, and locked into place by means of simple mortise-and-tenon joints. In La Défense, the units could be stacked as many as 25 high, but Malka's design could be applied to the side of any building.

To get in and out of their homes, residents could catch elevators among the offices on either side of the arch—the two sides of the arch would be connected by elevated catwalks supported by suspension cables—and move from house to house by way of more catwalks, attached to the scaffold itself.

Malka's vision of close-packed homes has precedent, particularly in Japan, where small-space living has been common for decades. In 1952 the architect Makoto Masuzawa built the 538-square-foot Minimum House. Architect Makoto Koizumi revived the design, which can house a family of five, in 2002; the Tokyo firm Boo-Hoo-Woo currently produces a line of 15 different dwellings for tiny urban lots based on Koizumi's revival of the Minimum House (9tubohouse.com/eng). In Amsterdam, Keetwonen, a high-density dormitory made of shipping containers, already houses students in 1,000 studio apartments (tempohousing.com). And someday, when even Los Angeles needs to give up its sprawling ways, architect Houston Drum will be ready with his design for the 25-Hour City, a 1,900-foot-high multi-tower skyscraper that houses 800,000 Angelinos at 26 times the city's current population density (houstondrum.com).



THE FUTURE OF THE HOME

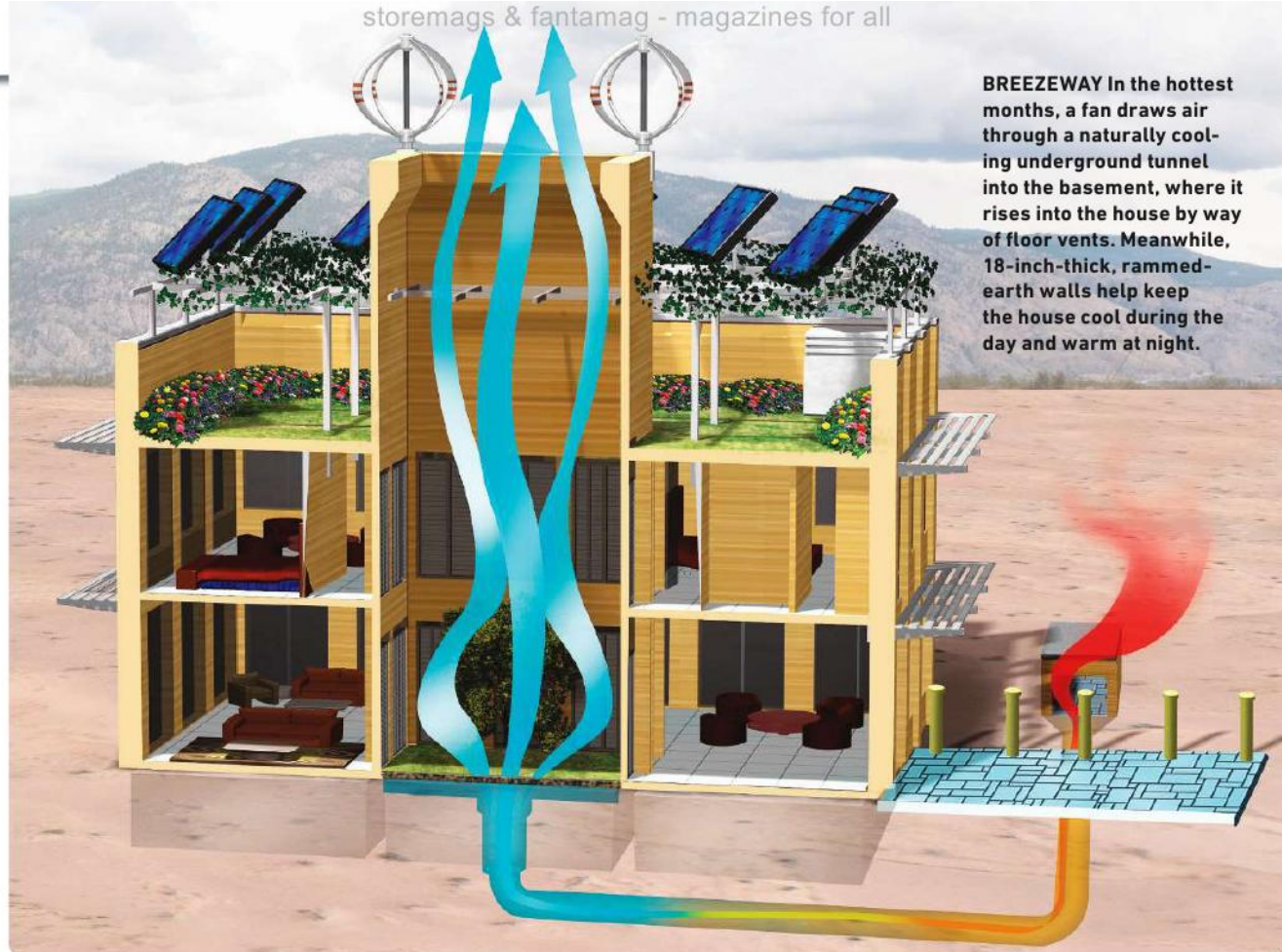
THE OASIS The Positive Impact House harvests energy and water from the environment for self-sufficient living.



SURPLUS POWER
Roof-mounted solar cells and eggbeater turbines together generate nearly twice the house's daily energy needs.

KEVIN HAND

BREEZEWAY In the hottest months, a fan draws air through a naturally cooling underground tunnel into the basement, where it rises into the house by way of floor vents. Meanwhile, 18-inch-thick, rammed-earth walls help keep the house cool during the day and warm at night.



PROBLEM

DESERTIFICATION

SOLUTION: POSITIVE IMPACT HOUSE

DESIGNER: ROBERT PERRY

One of the paradoxes of global warming is that even as it leads to flooding in some parts of the world, it will lead to severe water shortages in others. According to the United Nations, climate change is likely to reduce rainfall in drylands, which cover 41 percent of the land on Earth, including much of the American West. In 2007, the U.N. estimated that desertification could eventually affect some one billion people in at least 100 countries.

Yet architect Robert Perry of Studied Impact Design, which operates out of Pittsburgh and Dubai, proposes that deserts need not be unlivable, or even uncomfortable. His Positive Impact House, a 3,200-square-foot single-family home, is not only designed to draw enough water and cool air from the environment to sustain five people, it will also send energy back into the grid.

The water comes by way of an atmospheric water generator, similar to commercial units used today. These devices run refrigerant through

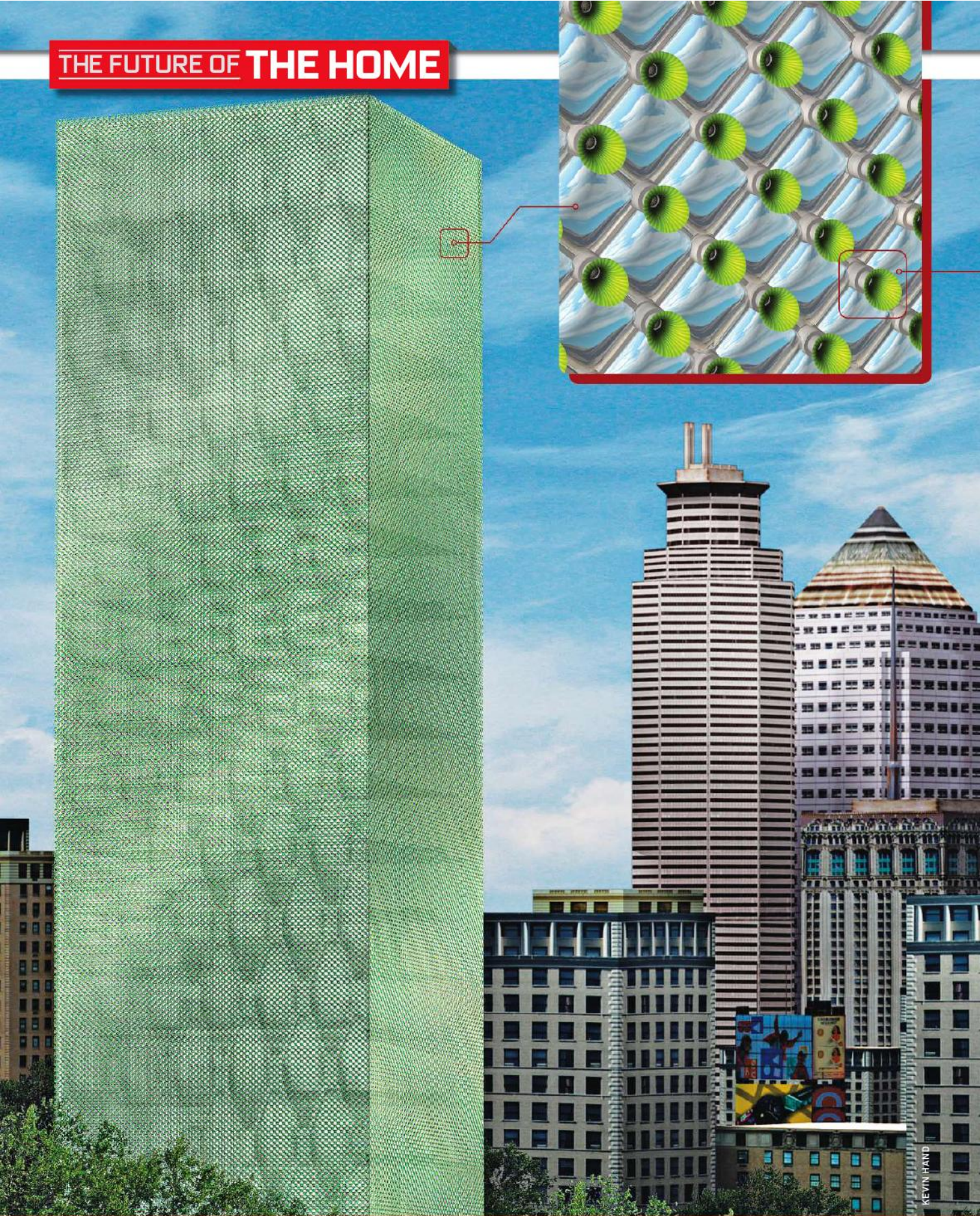
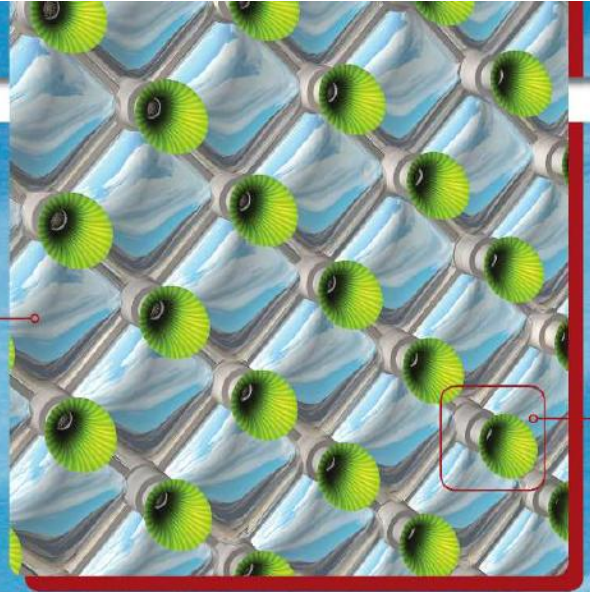
metal coils, which attract condensation that is then funneled into a purifying holding tank. (The desert air is moister than you might think; Dubai, for example, averages 80 percent relative humidity at certain times of day in January.) Two generators would produce enough freshwater for drinking and showering, and the shower water would be recycled for use in flushing toilets and growing food. (A related composting system would also generate biogas for cooking.)

Most of the year, the natural flow of air through the house's windows would be enough to cool it. But during the hottest months, a fan would draw hot outdoor air into an underground chamber, where the temperature is 50°F to 60° year-round, and then into the basement and up through floor vents. As the cool air warms back up again, it rises and escapes through a 200-square-foot interior courtyard, whose slim vertical cavity would create a wind tower.

The 24 panels of roof-mounted, sun-tracking, concentrated photovoltaics, which use lenses

to magnify solar rays by a factor of as much as 2,000, would be capable of generating all of the 80 kilowatt-hours of electricity the homeowners consume daily. Eggbeater wind turbines on the roof would produce another 40 kilowatt-hours. The extra energy would help with any sudden need for additional power, but on a normal day they could pump it back into the grid, thereby generating income. In the U.S., a homeowner sending 40 kilowatt-hours of energy to the grid every day would earn as much as \$3,000 annually.

Nearly all of this technology is in small-scale use today. A nonprofit group called FogQuest is harvesting fog to provide water to Ethiopian villages. In Zimbabwe, the Eastgate Centre shopping mall uses huge, perforated, chimney-shaped structures to draw air in from the outside. (Zimbabwe is hot, but air that moves is cooler than stagnant air.) And in Orange County, California, the Groundwater Replenishment System makes sewer water suitable for drinking (gwrsystem.com).



KEVIN HAND

PROBLEM

POLLUTION

SOLUTION: SUSTAINABLE HABITAT 2020

DESIGNER: PHILIPS DESIGN

In the coming decades, advances in pollution control may not be enough to counteract the air- and water-poisoning effects of dual explosions in population and energy consumption. Within 20 years the number of cars in the world will rise to two billion, and most of them will be powered by gasoline or diesel. By 2100 air quality in Southern California is expected to violate federal standards 50 more days a year than it does now. Pollution will be particularly vexing in fast-developing countries like China, which according to the World Bank is already home to 20 of the 30 most polluted cities in the world. In one third of China's cities, for example, the groundwater is contaminated. Buildings are part of the problem too. The nonprofit group Architecture 2030 estimates that the residential-building sector is responsible for about a fifth of global greenhouse-gas emissions.

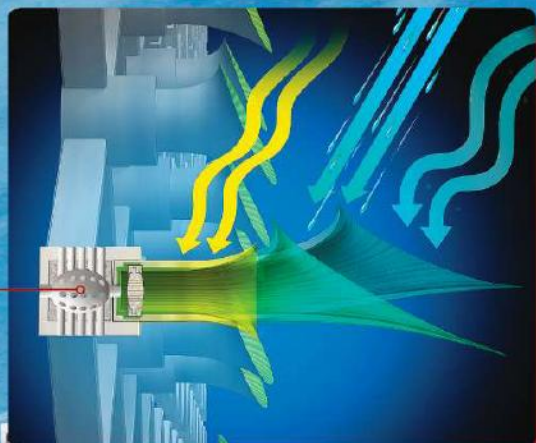
In response to these challenges, designers at the Dutch electronics giant Philips imagined Sustainable Habitat 2020, an apartment building engineered to make life healthy even in the smoggiest urban environment. "The question we're posing is a depressing one," says Clive van Heerden of Philips Design. "At this rate of urbanization, what do you do if the pessimists are right? How do we begin to start making buildings sustainable?"

The high-rise apartment tower, composed of hundreds of 431-square-foot units, is intended for future Chinese megacities. The multifunctional exterior skin is the most important part of the structure. Dotted with

suction-cup-shaped "funnels," it forms a membrane between the indoors and outdoors that controls the inflow of light, air and water.

The funnels are embedded with photovoltaic cells and sensors, which track humidity, wind direction, and the brightness and angle of the sun. As the sensors detect changing weather conditions, they direct the funnels to change into the most effective shape for the task at hand. For example, on clear days, the funnels follow the path of the sun like flowers, transmitting light indoors and generating enough solar power to provide all the building's electricity. (Energy stored during the day is used for lighting at night.) When it rains, the funnels change shape to become water-capturing cups. As rain trickles into the cones, the water is pumped to a cell structure behind the facade, where it is filtered, stored, and channeled into a closed-loop system in which everything, even toilet water, gets recycled. When it's breezy, the funnels elongate into a trumpet shape—a natural wind tunnel that directs air through a filter and then indoors. (When it's sunny and breezy, the funnels multitask.)

Other architects have begun working on projects in the same spirit as Sustainable Habitat 2020. The San Francisco firm IwamotoScott Architecture, for example, has proposed a low-rise dwelling called the Jellyfish House for a decommissioned military base on San Francisco Bay's Treasure Island. The project's creators say the house, with its permeable skin, will be like a living creature (iwamotoscott.com).



GREEN HOUSE Air-cleaning, solar-energy-harvesting, water-capturing funnels coat the Sustainable Habitat 2020 apartment building. The funnels change shape to make most efficient use of prevailing weather conditions.

CELL WALLS The translucence of exterior wall cells [at right] can be adjusted by touch. The interior wall [blue] works as a water tank, purifying and storing rainwater captured by the funnels on the apartment's exterior.

THE TINIEST TOCK

Atomic Clocks and the Search for Accuracy P.66

3-D SHIPWRECK

New Tech Lets You Explore the *Titanic* for Yourself P.36

POPULAR SCIENCE

26

Hot Products

High-Def 3-D
Movies (on a
Budget) P.19

THE
FUTURE
NOW



39 DAYS TO MARS

The 123,000-mph Plasma Engine That Will Take Us There

P.50

IS YOUR DINNER ENDANGERED?

DNA Detectives
Investigate

P.56

THE POPSCI BRILLIANT 10

America's Young
Science Geniuses

P.69

PLUS

NASA EXILED TO RUSSIA P.35 BIODIESEL FROM BUTTER P.45 OUR WRITER, ON FIRE P.88



NOVEMBER 2010

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CONTENTS

THIS MONTH'S GUIDE TO INNOVATION AND DISCOVERY

NOVEMBER '10
VOLUME 277 #5

FEATURES

THE OBSESSIVES

50 MARS IN 39 DAYS

NASA wants to send humans to Mars, but its preferred rocket technology is too slow. Former astronaut Franklin Chang Díaz has a plan—and an engine—to make the trip a reality.

By Sam Howe Verhovek



INNOVATORS 69 BRILLIANT 10

Meet the brightest young researchers in America, 10 emerging scientists who are creating bullets out of sound waves, making robots that school with fish, and predicting the next flu pandemic.

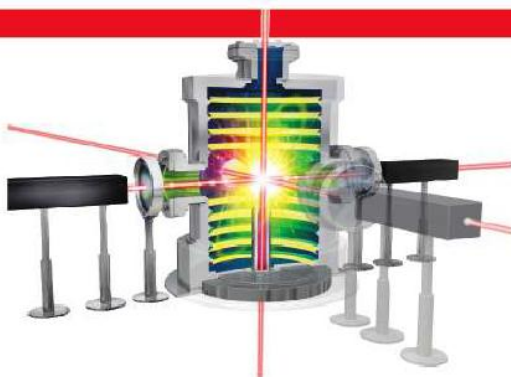


HOW IT WORKS

66 PERFECT TIMING

Strontium atomic clocks are three times as accurate as the current standard. Here's how they tick.

By Erika Villani



FIELDWORK

56 DINNER DETECTIVES

Scientists deploy DNA forensics to protect vanishing species.

By Laura Allen



MAGIC MUSIC MACHINE

A portable digital studio that's a one-stop solution for far-out sounds

Packing features into an electronic instrument—say, adding a recorder or sampler—tends to make for a bulky device with a seriously complicated menu system. Teenage Engineering's OP-1, part of a category of devices musicians call "grooveboxes," bucks that trend. It fits all the bells and whistles into a trim 11-by-4-inch slab that does away with menu-digging. It's a sophisticated, all-in-one noisemaker you can carry, and play, with one hand. —PETER KIRN

GET IT

Teenage Engineering OP-1
\$800 (est.; beta run in Oct.);
teenageengineering.com

INTUITIVE DISPLAY

In "tape recorder" mode, the AMOLED screen shows when you've reversed the sound or changed its speed, just like an analog tape.

SAMPLER The OP-1 can replay sounds recorded from a built-in microphone, a plugged-in instrument, a connected computer—even its onboard FM radio.

SYNTHESIZER

Four knobs shape sounds, such as simulated stringed instruments and classic vintage-inspired synths. With eight different synth engines inside, the OP-1 is as flexible as a full suite of hardware and software.

RECORDER The OP-1 lets musicians manipulate up to four tracks at once, warping and merging them together to produce new sounds. For example, changing the speed changes the pitch, as with an analog tape, and extreme changes produce glitchy distortion, as with digital audio.

FOUR MORE Electro-Instruments

KEYPAD

Free apps let musicians customize this minimalist 8-by-8-button keypad so they can do tricks such as slice beats and produce hypnotic melodies. **Monome Grayscale 64** \$500; monome.org

KEYBOARD

Dock your iPod or iPhone in Akai's keyboard to make a synthesizer. The piano keys control the app's synth sounds, drum kit and beat arrangements. **Akai SynthStation25** \$100; akaipro.com

TURNTABLE

The S4 marries computer DJing with the control of turntables. Magnets decrease resistance as you spin its jog wheels faster. **Native Instruments Traktor Kontrol S4** \$1,000; native-instruments.com

CLASSIC SYNTH ▶

Four decades ago, the Minimoog introduced the world to the all-in-one synth keyboard. This year's update has more keys (61 instead of 44) and a ribbon that transforms sound with finger pressure.



Musicians can also patch its circuitry to produce new sounds from scratch. **Moog Music Minimoog Voyager XL** \$5,000; moogmusic.com

FROM TOP: JOHN B. CARNETT; COURTESY MOOG MUSIC

YOUR LIFE IN 3-D

A new wave of affordable cameras brings amateur photography into the third dimension



With only a handful of 3-D channels and titles available, the task of filling the growing number of 3-D TV screens falls to snap-happy vacationers and amateur auteurs. They finally get their choice of 3-D cameras this fall, but the images they produce are not all created equal.

—STEVE MORGENSTERN

GOOD

SHOOT STILLS

Normally a camera needs two lenses (one for each eye) to produce a 3-D image, but Sony's Cyber-shot has the speed and software smarts to create the illusion of depth from only one. In 3-D mode, the camera snaps a burst of up to 100 images as you move it slowly from

side to side. Once that's done, its onboard software merges several frames from the burst into a single eye-popping image, which you can view on a 3-D-ready HDTV. **Sony Cyber-shot DSC-TX9** \$400; sonystyle.com

BETTER

SHOOT 720P VIDEO WITH STEREO SOUND

Shoot right out of the box: Fuji's W3 captures 3-D stills and video at the push of a button. Each of two lenses is backed by a 10-megapixel sensor that records separate, continuous video streams for the right and left eye. The camera's internal processor then combines both pictures into a single movie file, which it can send to a 3-D-capable HDTV via HDMI. **Fujifilm FinePix REAL 3D W3** \$500; fujifilmusa.com



BEST

SHOOT 1080i VIDEO WITH 5.1 SURROUND SOUND

A screw-on lens accessory turns Panasonic's top-tier high-def camcorder into a 3-D power player—while still maintaining a full 1,080 lines of horizontal resolution. The lens splits video into two right and left streams, and a sensor in the camcorder body saves these streams side by side in a movie file that's viewable on a 3-D HDTV (via HDMI) in near Blu-ray quality, complete with five-channel surround sound. **Panasonic HDC-SDT750** \$1,400; panasonic.com



FROM TOP: COURTESY SONY; COURTESY FUJIFILM; COURTESY PANASONIC

RAISING THE *TITANIC*

Robotic subs image the world's most famous shipwreck in 3-D before it crumbles

BOTTOM FEEDERS

Bacteria eating the steel hull make rusty icicle-looking formations. They may also generate electricity, contributing to the ship's corrosion.

To perform the first scientific survey of the entire *Titanic* site this summer, the crew of 30 researchers needed several miles of fiber-optic cable and a phalanx of robots. Now that they've imaged every surface of the historic ruins, all you'll need to view their 3-D photo-real model of the wreck is a computer.

The multimillion-dollar mission—funded by Premier Exhibitions, the company that holds the salvage rights to the ruins—pairs robotic-submarine experts from Woods Hole Oceanographic Institution in Massachusetts and other organizations with archaeologists eager to conduct the first full scientific survey of the site. Despite many previous explorations, including director James Cameron's documentary ventures to the deep, only about 60 percent of the *Titanic* had been photographed. During the multi-week cruise of the site, about 400 miles south of Newfoundland,

team members operated three underwater robots around the clock, scanning with sonar the ship's exterior and the entire four square miles of artifacts that the *Titanic* scattered as it sank and then shooting high-definition 3-D video and more than 100,000 photos.

This month the team will stitch together the sonar and optical data to produce a 3-D model of the bow, but it could take another year to convert the 200 terabytes of data into a consumer product. In the meantime, raw footage will help scientists determine exactly how the ship sank. "How did the boat snap in half? Did the bow really plow in nose-first?" asks David Gallo, the co-expedition leader and Woods Hole's director of special projects. "We'll have all these clues, such as the scattered pieces of the hull's midsection, to put together in detail how the *Titanic* came apart. It will be like a CSI of *Titanic*."—SUSANNAH F. LOCKE

the center changed hands, many experienced Star City instructors transferred to the military, which has also raised some doubt about the overall quality of training.

The advisory board also noted that the agency's own "resource limitations"—NASA-speak for a lack of qualified instructors and money—could affect the safety of space operations. That was made apparent in August, when astronauts performed a critical

spacewalk to replace a failed ISS cooling pump. They did so without the emergency option of using the Russian spacesuits and airlock because the practice of training on each country's suits and airlocks was dropped a few years ago. "It was a hard decision with known loss of capability," says a NASA insider. "In light of the recent emergency, it will be revisited."

The physical condition of Star City has also worsened with time

and a heavier workload. Military commanders made few upgrades to the center in the past few decades and seriously neglected basic maintenance. Instead of patching a leaky roof, for example, they hung a metal sheet over a computer mainframe to funnel ceiling drips into buckets.

The deputy head of Roskosmos, Vitaly Davydov, says that the dilapidated center his agency inherited needs nearly \$1 billion in repairs and renovations, 10 times its current

AUGUST 30 German researchers demonstrate the first real-time MRI machine, which generates images over the course of 20 milliseconds instead of several minutes.

HOW TO MAKE A VIRTUAL *TITANIC*

1. SET UP THE GRID

Researchers throw two sonar transponders overboard. Those sink 2.5 miles to the seafloor and begin broadcasting a signal that will later allow robots to triangulate their exact location as they collect data.

2. SEND IN THE SONAR

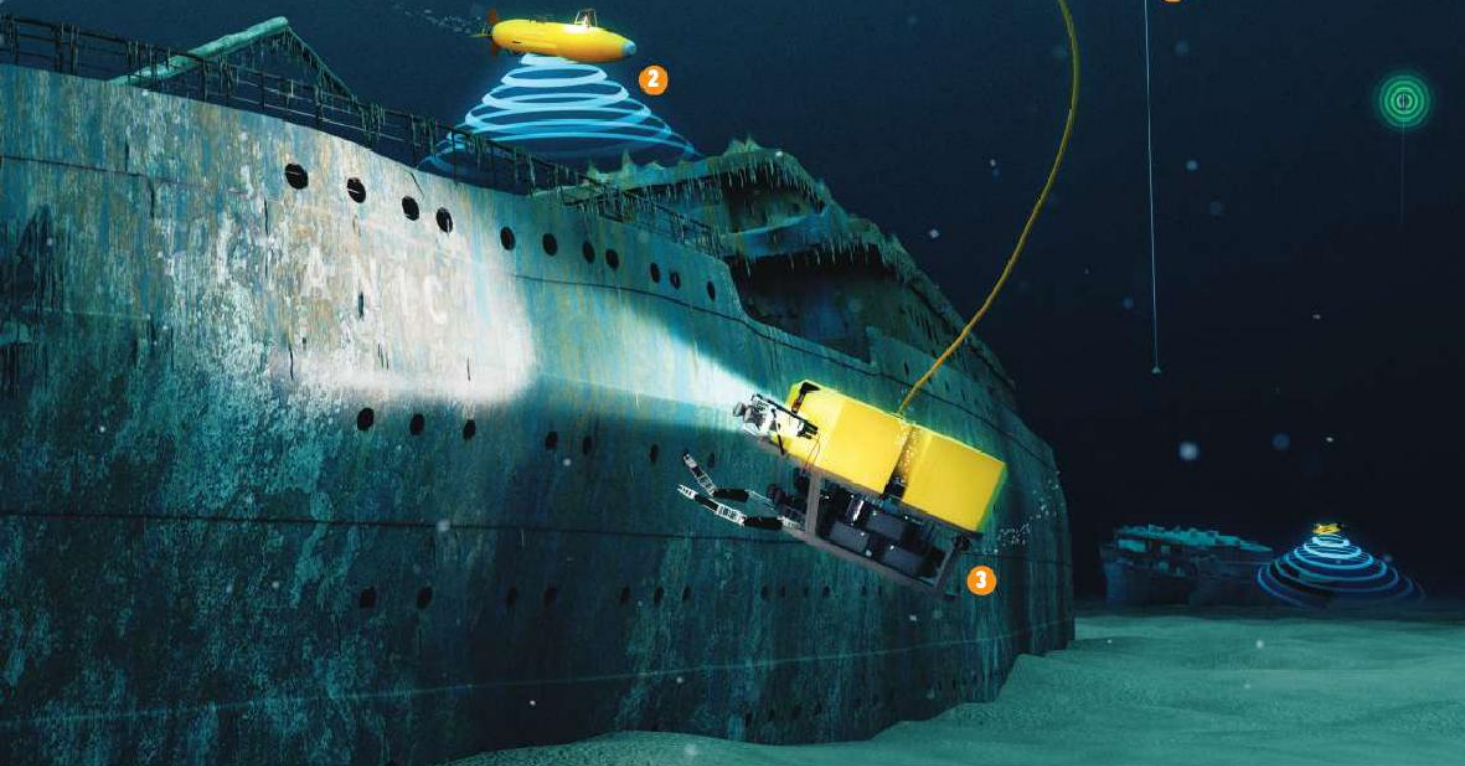
Two torpedo-shaped autonomous underwater vehicles (AUVs) sweep the four-square-mile site with 3-D sonar to outline the ship's shape and locate buried objects.

3. FILM THE WRECK

A remotely operated underwater vehicle joins the AUVs, taking high-definition 3-D video and photos of the ship down to the millimeter, as well as any relics on the seafloor.

4. BUILD A MODEL

Back on land, scientists analyze the sonar data to produce a 3-D model of the wreckage site. Then they wrap the structure in a mosaic of 3-D photos and video snapshots to produce the final photo-real, 3-D shipwreck.



STAR CITY'S COMPUTER SYSTEM IS ON PAR WITH NASA'S FROM THE 1980S, WITH NO INTERNET ACCESS.

GRAHAM MURDOCH

annual budget. Sergey Krikalyov, a decorated cosmonaut and Star City's new director of training, has complained that the center's computers and network are on par with what NASA ran in the 1980s and can't even connect to the Internet. Half of its automobiles and aircraft don't work, making it difficult to coordinate trainees, staff and repair technicians. He rates the training equipment as merely "functional."

Active astronauts, who would

only speak off record, insist they are confident that they can work through any difficulties. Although top officials are aware of the potential hazards, as of press time they hadn't developed a solution. They need one. Otherwise, NASA must either abandon manned spaceflight until it can rent out an American-manufactured spacecraft or continue hoping that astronauts' future errors are only embarrassing, and not worse.

—JIM OBERG

SEPTEMBER 7 Australian National University physicists use a laser beam to move small glass particles almost five feet. The technology might one day transport hazardous materials.

THE OBSESSIVES

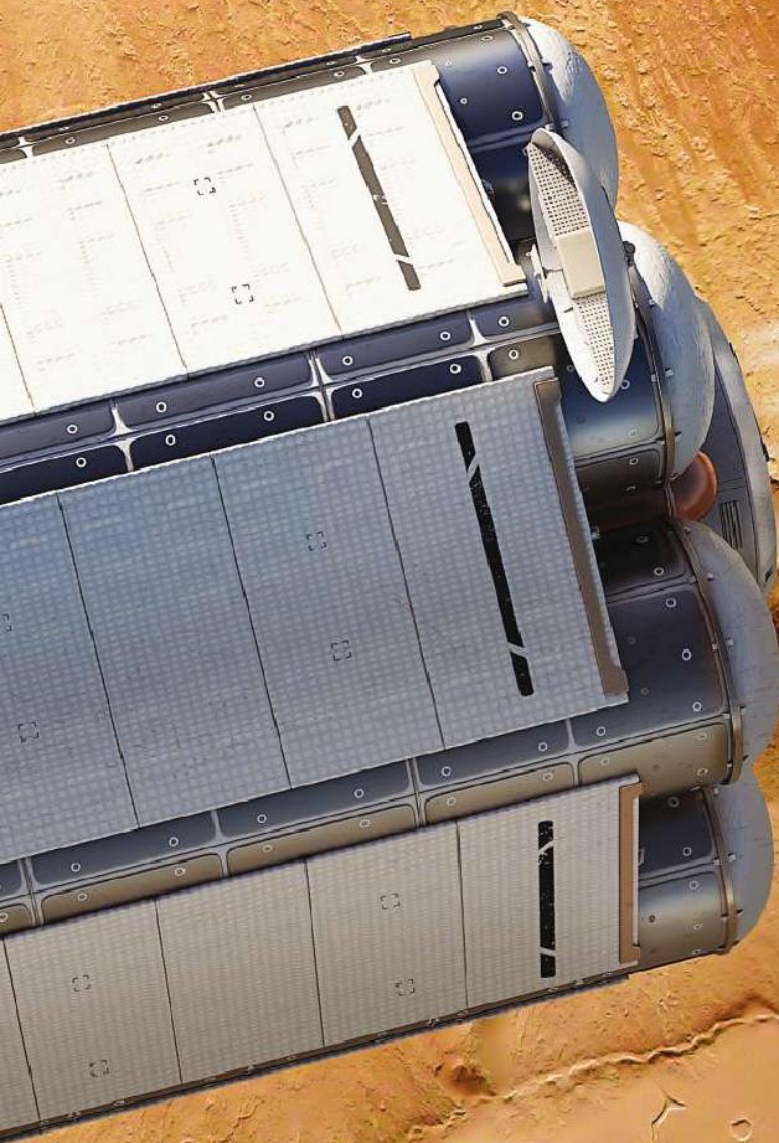
NEW FRONTIER An artist's vision of a plasma-powered craft, ringed by hydrogen tanks and nuclear reactors, arriving at Mars

MARS

50 POPULAR SCIENCE NOVEMBER 2010

True PDF release: storemags & fantamag

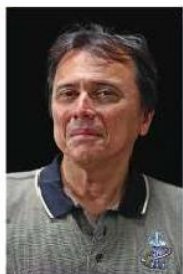
NICK KALOTERAKIS



The space shuttle, or anything built in its image, is far too slow to get astronauts anywhere beyond the moon alive. Veteran astronaut Franklin Chang Díaz has spent four decades developing his 123,000mph alternative: a rocket fueled by nuclear reactors and liquid hydrogen. Now NASA just might let it fly

IN 39 DAYS

BY SAM HOWE VERHOVEK PHOTOGRAPHS BY JOHN B. CARNETT



MAN ON THE GO
Franklin Chang Díaz, 60, hopes to reach Mars before his 80th birthday: "I just can't imagine not flying in a rocket I would build."

YOU MIGHT EXPECT TO FIND our brightest hope for sending astronauts to other planets in Houston, at NASA's Johnson Space Center, inside a high-security multibillion-dollar facility. But it's actually a few miles down the street, in a large warehouse behind a strip mall. This bland and uninviting building is the private aerospace start-up Ad Astra Rocket Company, and inside, founder Franklin Chang Díaz is building a rocket engine that's faster and more powerful than anything NASA has ever flown before. Speed, Chang Díaz believes, is the key to getting to Mars alive.

In fact, he tells me as we peer into a three-story test chamber, his engine will one day travel not just to the Red Planet, but to Jupiter and beyond.

I look skeptical, and Chang Díaz smiles politely. He's used to this reaction. He has been developing the concept of a plasma rocket since 1973, when he became a doctoral student at the Massachusetts Institute of Technology. His idea was this: Rocket fuel is a heavy and inefficient propellant. So instead he imagined building a spaceship engine that uses nuclear reactors to heat plasma to two million degrees. Magnetic fields would eject the hot gas out of the back of the engine. His calculations showed that a spaceship using such an engine could reach 123,000 miles per hour—New York to Los Angeles in about a minute.

Chang Díaz has spent nearly his entire career laboring to convince anyone who would listen that his idea will work, but that career has also taken several turns in the process. One day in 1980, he was pitching the unlimited potential of plasma rockets to yet another MIT professor. The professor listened patiently. "It sounds like borderline science fiction, I know," Chang Díaz was saying. Then the telephone rang. The professor held up a finger. "Why, yes, he's right here," the surprised engineer said into the receiver, then handed it over. "Franklin, it's for you." NASA was on the line. The standout student from Costa Rica had been selected to become an astronaut, the first naturalized American ever chosen for NASA's most elite corps. "I was so excited, I was practically dancing," Chang Díaz recalls. "I almost accidentally strangled my professor with the telephone cord."

All astronauts have big dreams, but Franklin Chang Díaz's dreams are huge. As a college student, as a 25-year astronaut and as an entrepreneur, his single animating intention has always been to build—and fly—a rocketship to Mars. "Of course I wanted to be

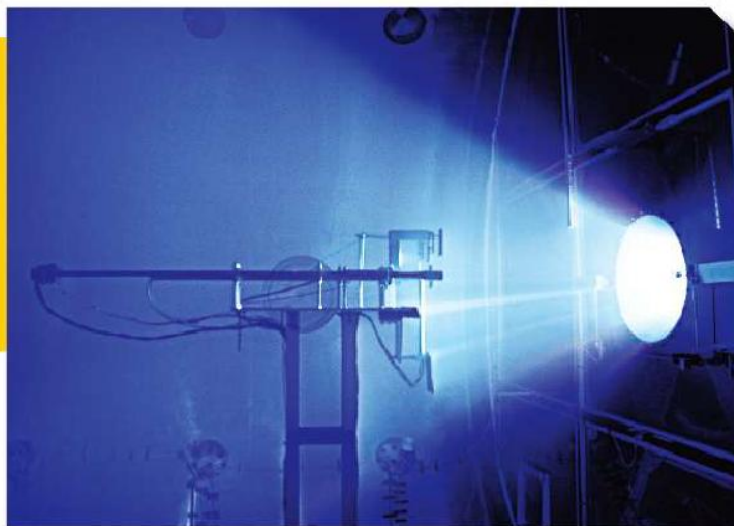
an astronaut, and of course I want to be able to fly in this," he says of his plasma-thrust rocket. "I mean, I just can't imagine *not* flying in a rocket I would build." And now he's close. In four years Chang Díaz will deploy his technology for the first time in space, when his company, aided by up to \$100 million in private funding, plans to test a small rocket on the International Space Station. If this rocket, most commonly known by its loose acronym, Vasimr, for Variable Specific Impulse Magnetoplasma Rocket, proves itself worthy, he has an aggressive timetable for constructing increasingly bigger plasma-thrust space vehicles.

Chang Díaz describes his dreams in relatively practical terms. He doesn't intend to go straight to Mars. First he will develop rockets that perform the more quotidian aspects of space maintenance needed by private companies and by the government: fixing, repositioning, or reboosting wayward satellites; clearing out the ever-growing whirl of "space junk" up there; fetching the stuff that can be salvaged. "Absolutely, fine, I'm not too proud to say it. We're basically running a trucking business here," he says. "We'll be sort of a Triple-A tow truck in space. We're happy to be a local garbage collector in space. That's a reliable, sustainable, affordable business, and that's how you grow."

Eventually, though, Chang Díaz intends to build more than an extraterrestrial trucking business, and his ambitions happen to coincide with Barack Obama's call for a privatized space industry that supports exploration well beyond the moon. "We'll start by sending astronauts to an asteroid for the first time in history," Obama said in a major NASA-related address earlier this year at Kennedy Space Center. "By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth."

Such a belief may seem overly ambitious, but the goals of aviation have always seemed that way. In October 1903, for instance, astronomer Simon Newcomb, the founding president of the American Astronomical Society, spelled out a series of reasons why the concept of powered flight was dubious. "May not our mechanicians," he asked, "be ultimately forced to admit that aerial flight is one of the great class of problems with which man can never cope, and give up all attempts to grapple with it?" Less than two months later, the

**"WE'RE HAPPY TO BE
A LOCAL GARBAGE
COLLECTOR IN SPACE."**



Wright brothers flew at Kitty Hawk. And in the 1920s a young man named Frank Whittle was coming up with drawings for a theoretical engine very different from the propeller-driven kind, one that might scoop in air through turbines and fire it through a series of “jet” nozzles. “Very interesting, Whittle, my boy,” said one of his professors of aeronautical engineering at the University of Cambridge. “But it will never work.”

THE CHASE

Chang Díaz decided he wanted to be an astronaut at the age of seven, when his mother explained the U.S.-Soviet space race to him. He went out that night to stare at the stars and look for *Sputnik*. But he soon realized that he had a problem. He happened to be a citizen of Costa Rica, and Costa Rica had no space program. When he was a teenager, he sent a letter to NASA asking how to become an astronaut. He got a letter back saying that to fly with NASA, he must be an American citizen. Boldness runs in his family—his Chinese grandfather fought against the Qing dynasty and fled to Costa Rica during a crackdown on the Nationalist movement. So Chang Díaz was not about to let a thing like citizenship deter him.

After graduating high school, intent on joining NASA, Chang Díaz went to live with relatives in

Connecticut. Despite his limited English, he won a University of Connecticut scholarship, one reserved for American citizens. Somebody somehow thought Costa Rica was Puerto Rico, he recalls with a laugh, and after the mistake was pointed out, he was told that the scholarship was being withdrawn. He appealed to university administrators, who agreed to take up his cause with the state, and part of the scholarship was restored, enough to make it possible for him to attend college.

His work was so outstanding there that he was accepted into MIT’s doctoral program for nuclear engineering. Then he applied to be an astronaut. NASA turned him down. (Chang Díaz says it was probably because his application for U.S. citizenship had yet to go through.) After he became naturalized—he now holds dual American–Costa Rican citizenship—he tried again, as one of nearly 4,000 applicants for 19 open positions. His plasma-physics doctorate, his singular focus on spaceship engines, his superb physical condition and his obvious drive combined to make him one of NASA’s select.

UNEARTHLY GLOW

A 200-kilowatt prototype of the VASIMR engine test-fires inside a pressurized chamber that simulates the vacuum of space.

THE OBSESSIVES

POWER HOUSE

A chamber bigger than a school bus houses a prototype of the Vasimr engine. Firing the engine is costly, so scientists often rely on an engine simulator [bottom right] to refine their designs.

Being an astronaut, Chang Díaz sees now, helped him to focus even more on his own vision, and it left him with a much stronger belief that speed was of the essence to get to Mars and beyond. “Believe me,” he says, “nobody will want to sit around in a spacecraft for six to eight months if you know you can get there faster.”

In many ways, Chang Díaz sees long-range space travel as the ultimate solution to the ultimate problem. The human race, he argues, will one day inevitably conclude that it has to live elsewhere in order to survive. It is also very possible, Chang Díaz concludes, that as resources dry up on Earth, other, potentially more profitable ones may be out there in the cosmos—something vastly more useful for batteries than lithium, perhaps, or for conductivity than copper.

“Whether we’ll find gold or riches or something we can’t even imagine,” he says, “we’ll never know until we arrive there to find out. I really don’t even see Mars as the end point; I see it as more of a waypoint. We’ll open up the entire solar system. Someday we’ll find life out there, and everything will change.”

Chang Díaz compares space exploration as it has been practiced thus far to exploration as it was practiced in the early years of the American frontier, when Lewis and Clark’s government-backed expedition brought back a trove of knowledge about the American West. The next phase, he believes, will be much more like the era of growth in the mid-1800s, when private railroads and mining outfits, helped along by land grants and other government aid, opened the West to epic expansion and settlement.

But, he says, space exploration isn’t simply a question of national achievement anymore. “We no longer have a big confrontation between the U.S. and the Soviets,” he says. “It’s totally different now. We all need each other to make this work.” He hopes U.S. citizens will be involved, but even that is by no means certain. “Countries like Brazil, India, China, some in Europe—there’s a lot of the same chemistry that the U.S. was feeling, say, 50 or 100 years ago. It’s a new club of developers.”

To hear Chang Díaz describe it, we’re on the verge of a shift from a nationalistic march toward dominance to a much more open and improvisational approach to innovation. If that’s true, it’s worth noting that he emerged from 25 years at NASA with his sense of improvisation intact.

In 2000, as part of a joint American-Russian survival-training program for crews visiting the ISS, Chang Díaz flew 60 miles west of Moscow for a round of practice drills. The instructors informed him and his two fellow crew members—Kalpana Chawla, killed in 2003 aboard the space shuttle *Columbia*, and a Russian cosmonaut that Chang Díaz describes as being physically much bigger than both of them—that they would need to simulate a mishap that had befallen an earlier



mission in which the descent capsule had landed in the midst of a blizzard, and it took rescuers 48 hours to reach it. From now on, the Russians told him, all *Soyuz* crew must train for those conditions.

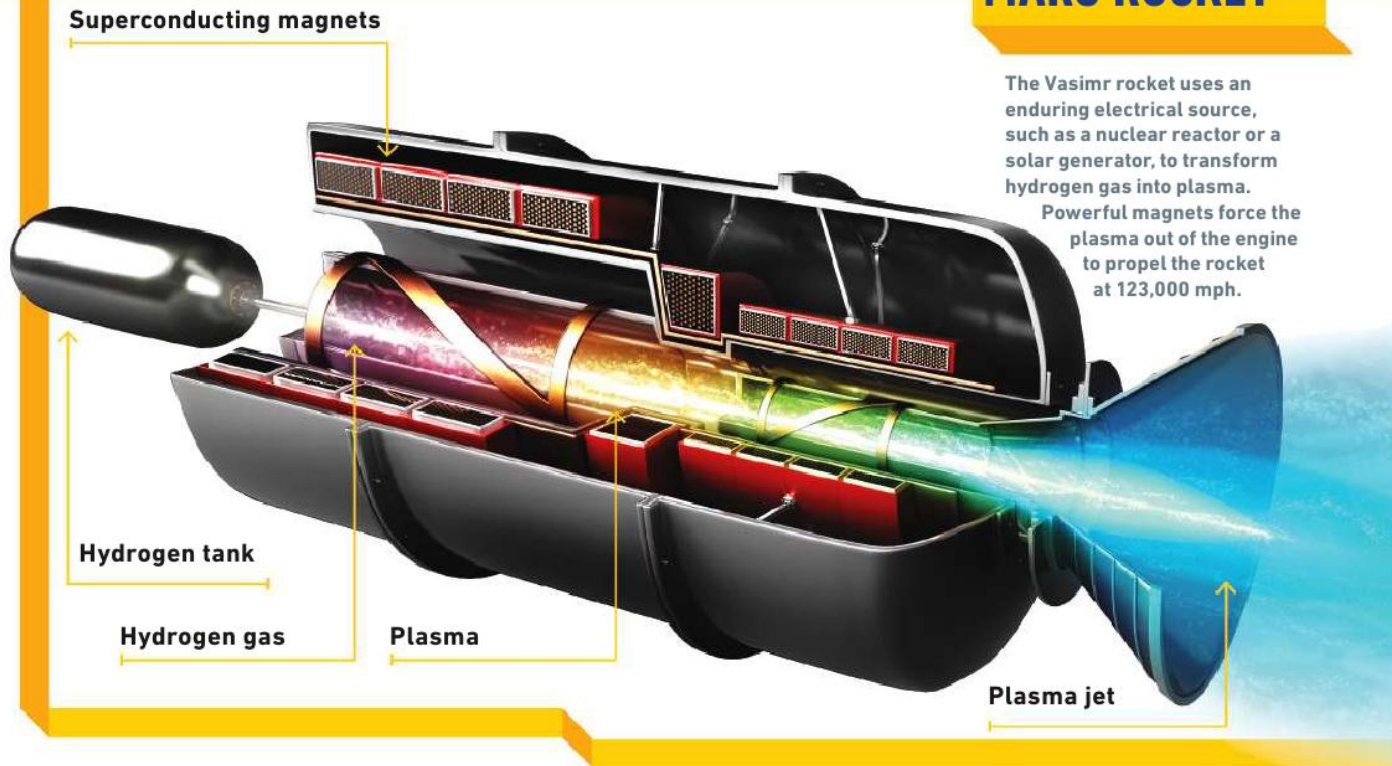
That’s a bit much, Chang Díaz remembers thinking. “Why wouldn’t I just delay the reentry by a moment and land in Fiji, or the Indian Ocean, or somewhere else warm and pleasant?” But that was the assignment, and so the trio sat in full flight gear inside a half-buried capsule as engineers heated up the exterior to reentry temperatures with a blowtorch. “It was a sauna,” he says.

The crew then had to remove their suits and don survival gear. The capsule was so tight that the process took the better part of a day, with each astronaut taking turns being helped out of one suit and into the other. Finally, they emerged into blinding snow and looked at their manual, which told them to build a shelter. Chang Díaz rolls his eyes at the memory.

Turning to his freezing teammates, he told them to gather up the capsule’s parachute silk. His father-in-law, during hunting trips in Montana, had taught him how to build a winter teepee. With the trunks of nearby birch trees and the silk, he improvised. Half an hour later, he had a fire burning inside, and in short order the three were sitting in their socks, dry and comfortable.

Soon a face poked through the flap. The Russians, watching from a ridge through binoculars, wanted to know what was going on. A teepee was not in any

THE FASTEST MARS ROCKET



The VASIMR rocket uses an enduring electrical source, such as a nuclear reactor or a solar generator, to transform hydrogen gas into plasma.

Powerful magnets force the plasma out of the engine to propel the rocket at 123,000 mph.

“MARS IS MORE OF A WAYPOINT. WE’LL OPEN UP THE ENTIRE SOLAR SYSTEM. SOMEDAY WE’LL FIND LIFE OUT THERE.”

manual. Was everyone all right? The crew smiled. We’re fine, Chang Díaz told them. You look so cold. Come on in. So the observers joined them, sat down, doffed their jackets, and sipped tea.

THE CHALLENGE

Chang Díaz, of all people, knows how hard it is to return safely to Earth. His career was bookended by death—death that could have been his own but for the routine tweaks of NASA’s scheduling log. The agency decided to pull him off his first scheduled mission on the space shuttle *Challenger* in 1986 and put him on the mission just before instead. Sixteen days later, newly returned to Earth, he watched his close friends and colleagues perish when *Challenger* exploded 73 seconds after takeoff. He went on to fly a total of seven missions between 1986 and 2002—he’s tied for the all-time record among astronauts—and logged 1,601 hours beyond Earth’s atmosphere. Then, a few months after his final mission, *Columbia* broke apart during reentry, killing all seven people aboard.

Chang Díaz’s invention will do little to reduce the

dangers of liftoff. Plasma engines depend on the vacuum of space and still require “venerable chemical rockets,” as Chang Díaz calls them, to reach Earth orbit. But outer space is where his work stands to vastly improve the safety of a crew. As he points out, a lot can go wrong en route to another planet. The limitation of space travel with a conventional rocket is that the rocket must use its entire fuel supply at once in a single, controlled explosion to reach Earth orbit. It then coasts along at a mostly uniform speed until it enters Mars’s gravity. NASA estimates that such a trip would take about seven months. During that time, Chang Díaz explains, there is no abort procedure. The ship cannot change course. If an accident occurs, Earth would be watching, in a 10-minute communications delay, the slow death of the crew. “Chemical rockets are not going to get us to Mars,” he says flatly. “It’s just too long a trip.”

A plasma rocket like VASIMR, on the other hand, sustains propulsion over the entire journey. It accelerates gradually, reaching a maximum speed of 34 miles per second over 23 days. That’s at least four times as fast as any chemical

[CONTINUED ON PAGE 102]

SPACEFLIGHT

EJECTION SEAT

If something goes wrong during the takeoff of NASA's new Ares 1 rocket, the dart-shaped Launch Abort System (LAS) atop the Orion crew capsule will lift the astronauts to safety.

SOLID PROPELLANT

All 4,700 pounds of fuel in the abort motor burn in less than three seconds—about three times as rapidly as in the space shuttle's boosters.

BOOST PROTECTIVE COVER

This surrounds the Orion crew capsule and shields it from the hot engine exhaust.

ORION CREW CAPSULE

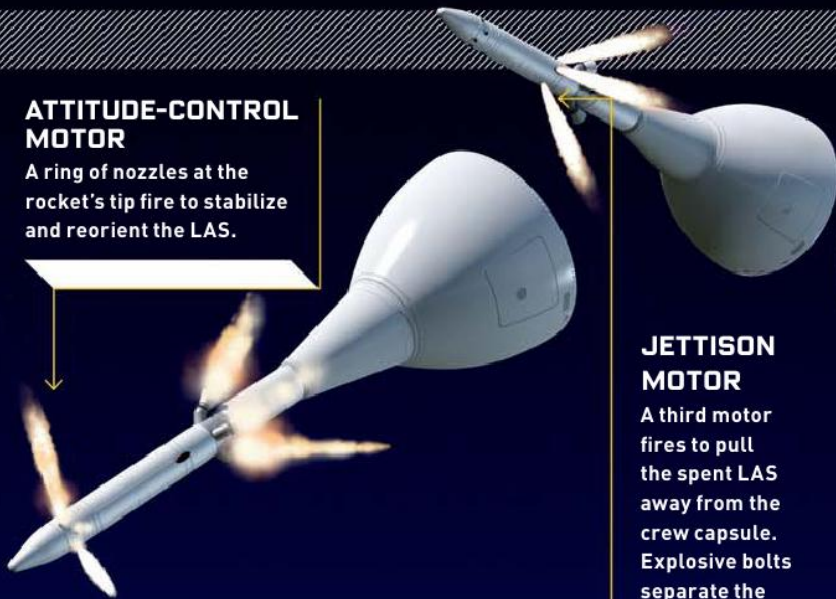
While launching away from a failing Ares 1 rocket, the four to six astronauts in the crew capsule could experience up to 11 Gs.

ABORT MOTOR

Exhaust vents through nozzles at the front of the abort motor.

ATTITUDE-CONTROL MOTOR

A ring of nozzles at the rocket's tip fire to stabilize and reorient the LAS.

**JETTISON MOTOR**

A third motor fires to pull the spent LAS away from the crew capsule. Explosive bolts separate the two units.

THREE-STAGE PARACHUTES

Once the capsule reaches a safe altitude, a series of parachutes deploys and brings the crew back to Earth.



NASA'S ESCAPE POD

THE ASTRONAUTS' VARIATION ON THE EJECTION SEAT SENDS THEM HURTLING A MILE AWAY FROM DANGER IN A MATTER OF SECONDS

BY DAWN STOVER ILLUSTRATION BY BOB SAULS

As early as 2015, the Ares 1 rocket, carrying the Orion crew capsule, could replace the space shuttle. With more than two and a half times the interior space of Apollo-era crew capsules, Orion can deliver a crew of six to the International Space Station and up to four astronauts to the moon. And if something goes wrong within the first 300,000 feet of the rocket's ascent, the Launch Abort System (LAS) will whisk the astronauts to safety.

1. CUT AND RUN

Step one: The abort motor fires and generates 400,000 pounds of thrust, shooting the Orion capsule up and away from the rocket, reaching 450 mph in less than three seconds. The hot gas from the engine is forced through a 155-degree turn in the motor's titanium manifold so that it exits through nozzles at the front of the motor, directed at an angle that keeps it from directly hitting the crew capsule. A fiberglass cover protects the capsule further.

2. SHAKE IT OFF

After the abort motor burns out, the LAS coasts, guided by the attitude-control motor. The engine's small nozzles, arranged in a ring around the LAS's tip, fire according to an autonomous flight computer to reorient and steady the spacecraft. The attitude-control motor is capable of spinning the LAS around in any direction—whatever it takes to get it upright and steady in preparation for the next step.

3. GLIDE HOME

About five seconds after the LAS reaches the proper orientation, a third motor fires to pull the spent abort system away from the crew capsule; explosive bolts separate the two. Parachutes deploy in three stages from the capsule to slow its descent to Earth. Ideally, the capsule will land in the ocean. If it hits solid ground, the Orion capsule will crumple to absorb the blow, and the astronauts' shock-absorbing seats will keep them safe. Scared to death, but safe.





STAR TREK

Inside This Summer's Sci-Tech Epics

CHINA ATTACKS

REVEALED: The Coming Hacker Offensive **P.60**

POPULAR SCIENCE

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P.15

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THE FUTURE OF TRAVEL

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rotor lets the two-seat Sarus
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MAY 2009





CONTENTS

THIS MONTH'S GUIDE TO INNOVATION AND DISCOVERY

MAY '09

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FEATURES

THE FUTURE OF TRAVEL P. 36

● PART 1: GETTING THERE

36 PLANES, TRAINS AND SUPERSONIC SPACESHIPS: A VISION FOR MAKING THE FUTURE OF TRAVEL FASTER, GREENER AND MORE FUN

Everyone wants to get away, but without the flight delays, gridlock and stratospheric gas prices. Welcome aboard the future of travel, from a 50-passenger "spaceliner" that makes the New York-Sydney run in less than 90 minutes to a bullet train that picks up passengers without stopping.

By Cliff Kuang

● PART 2: TOP DESTINATIONS

44 GEEK GETAWAYS

Most tourists wouldn't visit a 6,000-ton, neutrino-catching particle accelerator on vacation. But you're not most tourists, are you? Trek to cryogenic facilities, earthquake simulators and ape camps with our authoritative guide to fascinating secret destinations across the U.S.

By Joe Kita

● PART 3: COMFORT

48 WHY AIRPLANE SEATS ARE SO MISERABLE

Nothing represents the worst of airline travel like the infinite discomfort of the seat itself. Our 6'4" reporter searches for a design that will cushion—and possibly save—his behind. By Eric Hagerman



THE FUTURE OF THE MILITARY

50 WAR GAMES

The Army's new weapons system will feature mouse-controlled missiles, helicopter drones and text-message intel—if it can just get the network online. By James Vlahos

POPSCI PREVIEW

58 POPSCI'S GUIDE TO SUMMER SCI-TECH MOVIES

Has Hollywood botched the science in this summer's blockbusters? By Gregory Mone

FIELDWORK

60 THE CHINA SYNDROME

The greatest threat to American cyber-security is hundreds of thousands of patriotic Chinese nerds, hacking for their country.

By Mara Hvistendahl



WHAT'S NEW

TECH THAT PUTS THE FUTURE IN THE PALM OF YOUR HAND



18

A Mercedes hybrid that runs on laptop batteries



20

The most powerful GPS cellphone



24

Hit the links with high-tech golf gear



NINTENDO DSi

SCREEN: Two 3.25-in. LCDs

CAMERA: 640x480-pixel resolution

AUDIO: Stereo speakers

INPUTS: Game card and SD card slots, Wi-Fi

SIZE: 5.4 x 2.9 x 0.74 in., 7.5 oz.

GET IT: \$170; nintendo.com

IT'S ALL A GAME

NINTENDO'S POCKET CONSOLE MORPHS THE WORLD AROUND YOU

Sure, the new DSi plays videogames, but it also lets you play with whatever you can see or hear. Sporting a doubly powerful processor and four times the RAM of its predecessor, the DSi

can manipulate images from its two cameras (one facing you and one facing out). Use the stylus to stretch, squeeze, color and otherwise manipulate a friend's face in the live onscreen preview, for example, then snap a digital caricature.

You can treat both audio recordings and song downloads like virtual Silly Putty, as your touchscreen strokes speed them up, slow them down, and change pitch permutations. The DSi also generates animations set to the beat of music, including a game in which Mario collects coins arranged to mimic the notes in your favorite song.

For old-school play, you can load in nearly all of the existing 850 DS games, plus inexpensive downloads from a new online store.—STEVE MORGENSTERN

WHAT'S NEW

NEWS RADIO

Get news and reminders from bed. This clock radio has its own e-mail address, so pals can send it messages—"Let's do breakfast!"—that appear onscreen. Notes and data feeds, such as weather, are transmitted over a nationwide wireless network. **Ambient Mist** \$200; ambientdevices.com



EVEN-HANDED

Staple 25 sheets of paper without bruising your hand. OXO's model has two hinges, one at the back and one in the middle, to transfer force across a larger area—so a palm works as well as a fist. **OXO Good Grips Desktop Stapler** \$20; staples.com

THE GOODS

12 MUST-HAVE PRODUCTS

BY AMANDA SCHUPAK



POWER-MOVE

Campers can charge their gadgets up to 50 percent faster with the first portable solar panel that follows the sun. Throughout the day, four light sensors signal a motor to rotate the panel toward the brightest spot in the sky. **Solar ChumAlong** \$400; scientificsonline.com



WASTE NOT

Save water by giving any toilet two flushes, one full version and one that uses half the water. PerfectFlush's electronic valve drains the tank for specified amounts of time.

Brondell PerfectFlush \$120; brondell.com



SAFE HOUSE

This Internet router runs security software to protect all the computers in your home. It blocks malicious Web pages and lets parents specify which sites kids can view.

Linksys WRT310N \$130 plus \$60/year; linksysbycisco.com

PAN-O-RAMA

Automatically create billboard-size panoramic photos. The GigaPan Epic holds your camera, tilts from one end of a scene to another, and uses a robotic finger to press the shutter button from 20 to 2,000 times. Included computer software stitches the pics into one image of up to 11,000 megapixels in which you can zoom in to see detailed close-ups. **GigaPan Epic** \$380; gigapansystems.com



PLANES TRAINS AND SUPERSONIC

BY CLIFF KUANG
ILLUSTRATION BY KEVIN HAND



2020

COMMERCIAL FLIGHT:

THE LONG, SKINNY TUBE has to go. Tasked with improving the nation's air transportation, NASA wants airplanes to burn 40 percent less fuel than a 777 by 2020 and 70 percent less by 2030. Not only that, it wants those same planes to be whisper-quiet. The best—and perhaps the only—way to reach these ambitious benchmarks is to design commercial planes more like stealth bombers and less like pencils.

This past winter, the agency awarded \$12.3 million to Boeing, Lockheed Martin and other companies to develop the so-called N+3-generation airplane—that is, a design three generations ahead of today's. The leading contender is the fabled blended-wing body, which replaces the conventional tube with a triangular shape. "It's the only design that we think can meet our fuel and noise goals," says Tony Strazisar, a senior technologist with NASA's Fundamental Aeronautics Program. With high-speed wind tests of scale models under way, the blended wing could take flight before 2020. Here's how it would work.



BODY SHAPE

The blended wing's fuselage relies on a triangular shape to reduce its surface area and generate 20 percent of its lift. Less surface area means less drag, and less drag means more fuel efficiency.



A vision for making travel faster, greener and more fun

SPACESHIPS

ENGINES

Gains in fuel efficiency and noise reduction could also come from embedding the engines into the topside of the fuselage. This produces less drag, and the airplane itself shields ground noise. The big challenge is figuring out how to design the air intakes to maximize airflow over the fuselage.

PASSENGER CABIN

The blended wing's widened fuselage will make for amphitheater-like seating, with long, wide rows. Of course, there will be fewer window seats, but the interior design could compensate through spaciousness or swanky amenities such as in-flight lounges, viewing areas or seat-back virtual windows.

CONTROLS

"Blended wings have been tried for years," says NASA's Tony Strazisar, "but they've always faltered because the lack of a tail creates instability." Boeing's solution: nearly 24 control flaps on the wing, with computerized control systems to coordinate them.

OTHER IDEAS TAKING OFF

THREE PATHS TO GREENER SKIES

2010: RECYCLING

The airline industry expects to retire more than 4,000 planes by 2023. Rather than junk their airplanes in the desert, Boeing and Airbus are developing plans to reuse and recycle as much as 85 percent of the materials in aircraft that are flying now, from tires and batteries to carbon fiber and hydraulic fluids.

2012: SEED FUEL

Montana's Sustainable Oils is breeding camelina seeds—a canola derivative—that can easily be refined into jet fuel. Camelina's main draw is that it can be grown quickly on fallow wheat fields, so it can slot into the existing agricultural infrastructure.

2020: ALGAL FUEL

In January, Continental performed the first algae-fueled flight in the U.S., flying an unmodified 737 for 90 minutes on a blend of half algae-derived fuel, half jet fuel. The next major step is to reduce the cost of squeezing a gallon of oil from algae from \$100 to \$2.

2050

HYPERSONIC COMMERCIAL FLIGHT:

DON'T LET TODAY'S anemic airline industry fool you: Supersonic flight will rise again. By 2015, 12 years after the last Concorde flew, Lockheed Martin expects to complete the Quiet Supersonic Transport, a business jet that can zip a dozen hotshots from Chicago to Paris in as little as four hours. But far more fun will be the "Spaceliner" under development by the German space agency DLR. Funded by the European Commission, the plane will be capable of flying 14,000 mph and delivering 50 passengers from New York to Sydney in less than 90 minutes—through space.

Think of the ship as a modified version of the space shuttle: a two-stage vehicle that takes off from a launchpad. "We're not talking about exotic technology," says Martin Sippel, the Spaceliner's chief investigator. "We're taking existing ideas and applying them in a way that makes economic sense for commercial travel." The idea is that by reducing the technical demands inherent in the space shuttle's design—such as how high and how fast the rig would fly—the Spaceliner could be safer than the shuttle, for a ticket price somewhat higher than a first-class ticket today. Here's how your hypersonic flight would work.

ROCKETS

The Spaceliner would lift off on the back of a rocket powered by liquid hydrogen/oxygen thrusters capable of 25 launches. After separation, the rocket engines would glide to a recovery site, making rapid reuse and refurbishment much less complicated. Spaceliner's Martin Sippel thinks the turnaround for the entire rig will be one to three days.

TAKEOFF

Within seven minutes, the airplane would reach the lower boundary of space, 62 miles up. At maximum altitude, it would be traveling faster than 14,000 mph—nearly as fast as the space shuttle. Instead of continuing up, it would dip into the atmosphere to generate lift and travel farther on less fuel. The extreme altitude means the sonic boom won't disturb people on the ground.

ENGINES

The space shuttle is a hodgepodge of engine technologies: three hydrogen/oxygen engines on the craft, plus the solid-fuel boosters. Solid fuel, though more energy-dense, is roughly 10 times the cost of liquid hydrogen and oxygen. The Spaceliner doesn't need quite so much thrust, and it has to run cheaper, so it will have just two engines, compared with the shuttle's three.

COOLING

Passing through the dense lower reaches of the atmosphere at many times the speed of sound can heat up the aircraft to 5,400°F. To keep it cool, DLR engineers have invented porous ceramic tiles that would "sweat" water. A major component of DLR's upcoming research will be refining the ceramics and doing larger-scale tests at faster wind-tunnel speeds.

SPACE TOURISM: 2010

THINKING ABOUT BOOKING A TICKET TO SPACE? CHECK OUT OUR GUIDE TO THE LEADING CARRIERS

Last year saw a big shakeout among would-be space-tourism operators. Hyped ventures by EADS Astrium and

Rocketplane Limited sputtered, while efforts by Armadillo Aerospace, SpaceDev and Blue Origin have quieted to a whisper.

But a handful of outfits are making steady progress, with \$200,000 tickets booked solid. We size up the competition.



VIRGIN GALACTIC

The Virgin rig comprises two aircraft: *WhiteKnightTwo* lofts *SpaceShipTwo* to 50,000 feet; then *SpaceShipTwo* accelerates to Mach 3 to reach the edge of space. Virgin test-flew *WhiteKnightTwo* last December and unveiled designs for *SpaceShipTwo* in January. Expect test flights later this year.



XCOR

XCOR's *Lynx* rocketplane has four liquid-oxygen/kerosene-fueled engines that propel it straight up at 1,500 mph. The company successfully tested the engines last December. It plans test flights by the middle of next year, with commercial rides by 2011. At least 20 people have already booked seats.



FAST 20XX

French aeronautics firm EADS Astrium suspended work on the ballyhooed *Spaceplane* in January, but Europe isn't dropping out of space tourism. The European Commission just inaugurated its FAST 20XX program to develop a *SpaceShipTwo* competitor. The craft will probably piggyback on an Airbus A380 up to 50,000 feet, and then a small hybrid rocket would power it to the end of space, 62 miles up.



SPACE ADVENTURES

Virginia-based Space Adventures books passengers on Russia's Soyuz-TMA capsule, but the company has now bought its own Soyuz mission for late 2011. Both passenger seats were open at press time—even though Google co-founder Sergey Brin has a \$5-million deposit on a future flight, he hasn't yet decided when he'll travel.

From liftoff to landing, it will take 2.5 hours, including about six minutes of weightlessness. With an apogee of 68 miles, the plane will push slightly past the defined boundary of space. The six passengers will sit in forward-facing, racecar-like seats behind the two pilots.

\$200,000 for the first 100 passengers

Initially Mojave Spaceport, then new spaceports in New Mexico and Sweden

More expensive than XCOR, but more likely to last long enough to drop prices. Already Virgin has \$30 million in pre-bookings from over 200 people. Obviously, the company's track record leads the other start-ups: The two-passenger *SpaceShipOne*, which used the same basic technology as its successor, won the X Prize in 2004.

Lynx will reach 38 miles in 30 minutes. During the four-minute apogee, you'll be weightless. But the real perk is that unlike on *SpaceShipTwo*, you'll get a one-on-one experience with the pilot. The craft has only two seats, and you sit shotgun next to him.

\$95,000—a comparative bargain—per flight

Mojave Spaceport, in California

The basic technology appears reliable. The question is, will the half-price discount over Virgin win out for penny-pinching pioneers? "Eventually there will be a price war," says Doug Graham, XCOR's spokesman. "The market is going to decide if floating around demands a premium over a front-row seat."

Very similar to Virgin's, reaching a similar altitude, inside a cabin that seats six to eight passengers

\$200,000 (est.)

Sweden

With a launch date set for 2015, the FAST 20XX can catch up to Virgin quickly if the political will remains. The passenger craft is based on an older shuttle prototype, *Phoenix*, which EADS Astrium successfully tested in 2004, and the engines will be similar to those on *SpaceShipTwo*.

Whereas the other options give you just minutes in zero G, the two-passenger, one-pilot Soyuz is the true astronaut experience, complete with training, a bone-crunching takeoff and an orbital flight in the tiny, cramped Soyuz capsule, 200 miles above Earth.

\$20 million+

Kazakhstan

The Soyuz is still the only craft to have ferried tourists into space, and it will continue doing so for the few moguls that can afford the price. But for the masses, Space Adventures is also very quietly seeking partners to develop a suborbital craft. "The [field] is so competitive that we're not talking about partners or timelines," says Space Adventures CEO Eric Anderson.

2011

SUPER TRAINS:



IN A PUSH to reduce carbon emissions and relieve crowded airports, trains are quickly replacing airplanes. Europe, with its long tradition of train travel, has been particularly aggressive. In 2007 the European Commission initiated a plan that will triple its high-speed-rail networks by 2020. The train-maker to watch? French firm Alstom, the name behind 70 percent of the trains that surpass 186 mph—nearly 650 of them. Its next-generation train, the AGV, just entered full-speed tests last December and in 2011 will be whizzing around Italy. If you're disappointed at the prospect of having to fly to Europe to ride the AGV, don't be. Alstom is in discussions to provide trains for the high-speed-rail system planned in California.

Here's a look at some of the big innovations that will let the AGV hit a top speed of 224 mph while offering a roomy, comfortable ride.

SHAPE

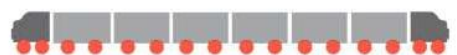
The aerodynamics of the AGV not only increase speed but also cut noise. At its top speed, the train makes as much clatter as its predecessor, the TGV, does at 200 mph—no mean feat, since noise increases exponentially with speed. It required smoothing every surface on the train, from the hoses between cars to the farings on the front bogies (also known as wheels and axles), as well reshaping the nose cone.

WHEELS

The AGV has "articulated" bogies. Usually every car in a train has two sets under it, just like your car does. But the AGV's bogies are placed *between* cars. Thus, a 656-foot train carrying 500 passengers requires 13 bogies rather than 16, with a weight savings of one ton each. So the entire train would weigh 17 percent less than a similarly sized conventional rig, while creating 10 to 15 percent less drag.

MOTORS

The AGV will be the first train powered by motors that use permanent magnets, rather than electrified copper coils, to produce a magnetic field. The design radically cuts energy use, and the smaller motors can sit under each car, rather than in engines at the ends of the train. That means a 14-car AGV can carry 20 percent more people than the TGV, with 30 percent lower energy costs. The rotors also generate electricity during braking, so the train returns 8 to 12 percent of the power it uses back to the grid.



Traditional: Wheels beneath cars



AGV: Wheels in between cars

A BETTER BOGIE

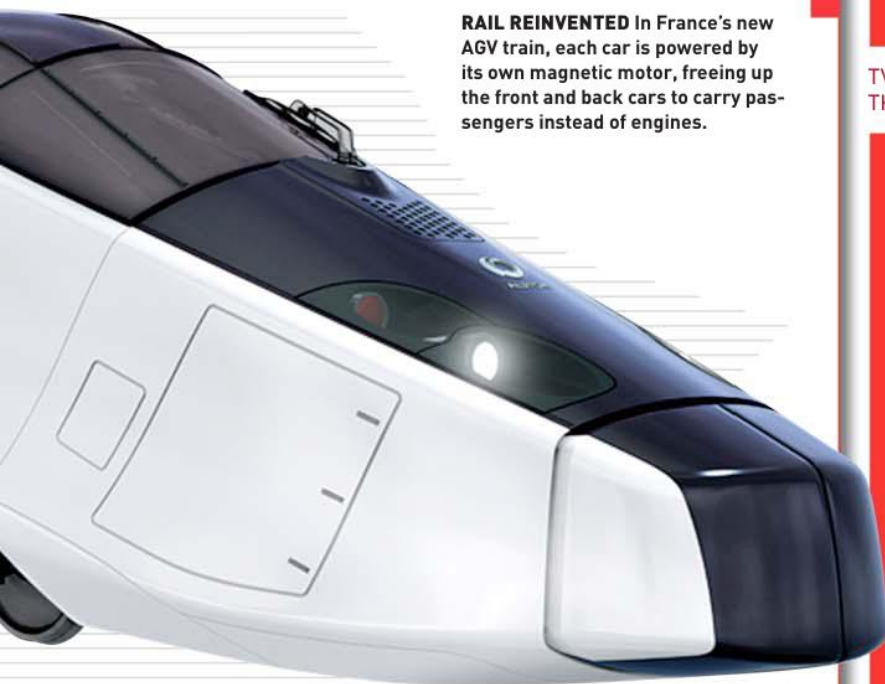
Primary suspension

Secondary suspension



Permanent-magnet motor

Wheel



RAIL REINVENTED In France's new AGV train, each car is powered by its own magnetic motor, freeing up the front and back cars to carry passengers instead of engines.

BRITS GET A CLEANER COMMUTE

TWO NEW TAKES ON GREENING
THE CLASSIC LONDON RIDE

London is revamping itself for the 2012 Olympic Games, and part of that will entail bringing back its iconic double-decker buses. Last winter, two co-winners were announced in a competition to redesign the Routemaster: Foster and Partners, an architecture firm, collaborating with Aston Martin; and Capoco, a leading bus designer. Their entries mix old-time design elements and new technology.

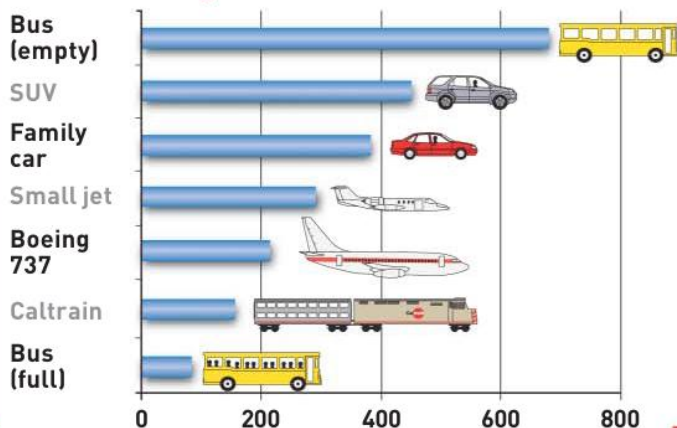
Both propose aluminum, monocoque frames to cut weight and minimize bulk, and easy-to-repair hybrid engines, with flywheels that would regenerate battery power during braking. Inside, the Capoco design hews closer to the old layout. But the Foster version [below] is more of a departure. "It's basically a mobile building," says Alistair Lenczner, a partner at the company. "We wanted to create a living room." The seats are recycled leather and the floor recycled wood. The layout riffs on the living-room feel: Downstairs are the typical forward-facing, flip-down seats, but upstairs the benches face each other.

Contractors are now bidding to build the buses, with production set to begin by 2011. They can use all or some of the elements in the winning designs, but looks will matter. "We have architecture competitions all the time," says Alan Ponsford, Capoco's design director. "But London's 8,000 buses affect more people's lives than any building would. The outcome should reflect that."

HOW GREEN IS YOUR TRAVEL?

Buses are more eco-friendly than planes, and both are more eco-friendly than cars. Right? Not necessarily. Fuel consumption and tailpipe emissions are only part of the picture. The correct answer factors in passenger occupancy, manufacturing processes and other indirect sources of carbon emissions. "Environmental thinking is getting away from just direct energy use and into the full repercussions," says Mikhail Chester, a postdoctoral researcher at the University of California at Berkeley. He and civil-engineering professor Arpad Horvath have created the most comprehensive life-cycle analysis of the transportation industry to date—seriously, it's thorough. For cars, it goes all the way down to the carbon required to build a road, emissions from gas tankers, and the computers that power the attendant insurance industry. Here are the results.

GRAMS OF CO₂ PER PASSENGER MILE



2012

PERSONAL PLANES:



PLUG-IN ROAD TRIPPING

PREFER DRIVING TO FLYING? WHAT TO EXPECT FROM THE NEWEST FLEET OF ELECTRIC CARS AND PLUG-INS ON THOSE LONG HAULS

The idea of electric-car travel invariably spawns jokes about extension cords the length of Texas. Meager ranges, multi-hour charging and a lack of highway electrical outlets mean that most consumers still consider pure-electric vehicles a fantasy. But when it comes to plug-in hybrids, there's no fooling: Today's technology can handle treks to Disney World, not just runs to the store. When the juice runs low on the Chevrolet Volt and the Fisker Karma, two plug-ins due out by next year, their small gasoline engines fire up to generate more

electricity and dramatically extend driving range. The result is family-friendly cars that can double the range of all-electric cars and can cruise from sea to shining sea and refuel in minutes. If you're determined to ditch gasoline completely or just need an urban runabout, the Tesla Roadster may be the ticket. But if your summer plans include suitcases and scenic overlooks, only the hybrids will eliminate the "range anxiety" that makes Americans leery of buying and banking on purely electric cars.

—LAWRENCE ULRICH

TESLA ROADSTER

THE RIDE An all-electric two-seater powered by lithium-ion batteries. Cost: \$109,000.

RANGE 244 miles in combined city/highway driving. Fully charges in less than 3.5 hours on 220-volt outlets.

PERFORMANCE 0–60 mph in 3.9 seconds; 185 kilowatts, 248 horsepower

ROAD-TRIP-WORTHY? If your vacation takes place on a racetrack, sure. Otherwise, most Teslas will stray as far from home as a pedigreed cat.



ILLUSTRATION: NICK KALOTERAKIS; PHOTOGRAPH: TESLA MOTORS



WHEEL FUN The spinning ring around the two-seat Sarus provides downward thrust for stable, helicopter-like takeoffs and then shifts vertically to propel the craft forward.

CARS AND COMMERCIAL JETS aren't the getaway craft they once were. Every year, Americans spend \$78 billion dealing with traffic alone. Meanwhile, the "friendly skies" don't seem so nice anymore. Commercial aviation is so crowded that NASA is already researching ways to restructure air traffic on a point-to-point model using small regional airports. Compare that with the current state of the private airplane. Gas efficiency is already on the order of cars—the new Icon A5, a light-sport aircraft on sale next year, will get 25 miles per gallon. And learning to fly has never been easier. A typical pilot's license costs about \$10,000 and requires 40 hours of training. But in 2004 the FAA created a new designation for light-sport planes: those with one engine, a flight ceiling below 10,000 feet and a top speed of less than 138 mph. Light-sport certification takes half as long as usual. In response, entrepreneurs are rushing forward with intriguing ideas and options.

SARUS

Few cities or suburbs can fit the long runways that even light aircraft require. So, the thinking goes, you need either a flying car or a hovercraft to make personal flight truly convenient. One of the most novel ideas out there is the Sarus [left]. Designed by Boston-based firm AeroCopter, the plane is ringed by a 21-foot rotor, which lifts it off the ground. In flight, the rotor tilts 87 degrees and then switches power to the rear rotors to propel it forward. Inventor Siamak Yassini has built a scale model and is now seeking funding for a full-scale prototype.

HY-BIRD SOLAR

LISA, a French manufacturer of sport planes, has paired with solar-cell maker Trina Solar to create an electric airplane, dubbed the Hy-Bird, whose 65-foot wings will be covered in flexible solar panels. Stocked with the sun's energy, batteries will power the plane during takeoffs and charge all the instruments. Once aloft, the plane's electric motor will run on a hydrogen fuel cell stored behind the pilot's seat. The company has built a scale model of the plane and hopes to have a full-scale model ready for flight by the end of the year.

MS-1

If you can't afford one of the fancier planes, you can always buy a kit and build a single-engine puddle jumper for about \$60,000. But an extra \$50,000 gets you a big upgrade: MySky's new MS-1, a sleek two-seater with a single 120-horsepower motor set to debut in August. Like the light-sport Icon A5, it's easy to fly, with two sticks for steering and throttle, and a top speed of 138 mph. It's about \$30,000 cheaper, though, and boasts better views—an enormous bubble canopy lets pilots see straight down and all around.

CHEVROLET VOLT

THE RIDE A plug-in hybrid that seats four; runs on an electric motor powered by lithium-ion batteries, plus a 1.4-liter, four-cylinder gasoline engine. Cost: \$40,000.
RANGE 40 miles; gas engine extends range to 300 miles. Charges in eight hours on household current, less than three hours on 220-volt outlets.
PERFORMANCE 0–60 mph in nine seconds; 110 kilowatts, 150 horsepower
ROAD-TRIP-WORTHY? Drive your Chevy to the levee and all points beyond.



FISKER KARMA

THE RIDE This year, former Aston Martin designer Henrik Fisker delivers an \$88,000 plug-in hybrid, four-person sedan that runs on dual electric motors powered by lithium-ion batteries, plus a 2.0-liter turbocharged four-cylinder engine.
RANGE 50 miles on electricity alone; gas engine extends its range to 300 miles. Charges in 5.5 hours on 220-volt current.



PERFORMANCE 0–60 mph in 5.8 seconds; 300 kilowatts, 408 horsepower
ROAD-TRIP-WORTHY? The Fisker is ready to dazzle valets, and its speed ensures that you won't be late for check-in. The downside is electric motors that hog trunk space.

P.62

DR. ROBOTO

A Gallery of Amazing Medical Machines

10 SECRETS

of the Apollo 11 Moon Landing **P.84**

POPULAR SCIENCE

**THE
FUTURE
NOW**

THE FUTURE OF ENERGY

POWER PLAN

**HOW TO
BUILD
A GREEN
HOME**

P.60

**EXTRAORDINARY
SOLUTIONS FOR
A CLEAN-ENERGY
CENTURY**

P.39

**ICELAND'S
GEOTHERMAL
BAILOUT**

P.50

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WHAT'S NEW

TECH THAT PUTS THE FUTURE IN THE PALM OF YOUR HAND



18

This car stops itself
—and accidents



20

A cheaper way to play
the latest videogames



22

A watch that talks
to gym machines



GRAND ILLUSION

AN ELECTRIC PIANO FOR
MOZARTS ON A BUDGET

A \$19,000 piano might not seem recession-friendly. But it's a bargain when it's nearly indistinguishable from one that costs \$100,000 more. The sole difference: The discount grand is digital.

Sound emanates from the entire body of the Yamaha AvantGrand, just as it does from a traditional, handbuilt grand's vibrating strings. Four separate sets of speakers, each complete with high-pitched tweeters and thumping

woofers, play tones recorded from corresponding locations on an actual piano. That outdoes other digital models, which replicate notes from only two positions.

Expert pianists will even notice the same subtle quiver in their fingertips as when strings resonate against keys, because a transducer under the keyboard trembles as you play. The only people who will miss the strings? Piano tuners.—SEÁN CAPTAIN

YAMAHA AVANTGRAND N3

AUDIO: 12 speakers, 16 amplifiers

VOICES: Grand piano, electric piano and harpsichord

SIZE: 58 x 47 x 68 in.

WEIGHT: 438 lbs.

PRICE: \$19,000

GET IT: yamaha.com

SATOSHI

POPSCI.COM See (and hear) a video at popsci.com/piano.

JULY 2009 POPULAR SCIENCE 13

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SOLAR POWER

THE BIG PICTURE “Solar power” no longer refers just to chunky photovoltaic panels. A variety of tools for turning sunlight into usable energy—thin-film solar, solar thermal, solar heating, and more—are undergoing a burst of technological acceleration. Whether it’s powering an entire housing development or simply heating your house, taken together, their potential is huge.

WHERE WE ARE: **12.4 GW** WHAT WE NEED BY 2050: **2,000 GW**

TECH TO WATCH: CONCENTRATING SOLAR THERMAL

A shortage of low-carbon power sources seems absurd when you consider that a nearby star bathes the planet in 85,000 terawatts of energy every year. We just have to capture it.

The Google-funded start-up eSolar has devised a relatively cheap and efficient form of solar power by refining concentrating solar thermal (CST), in which large mirror arrays focus light to create heat and ultimately electricity. Proponents say CST can make solar cost-competitive with coal within a decade. It is “probably the only thing that can be done at a big enough scale to produce terawatts,” says Bill Gross, eSolar’s CEO.

At the first eSolar power plant, a five-megawatt facility called Sierra situated northeast of Los Angeles, 24,000 mirrors gather the sunlight falling on 20 acres of land and train it on water-filled boiler units perched on top of towers. This creates temperatures of approximately 850°F, producing steam that turns an onsite turbine to generate electricity.

CST has been around since 1980, but in the 1990s a lack of public interest sent it into hibernation. Now public interest is back in a big way, and CST has awoken with a vengeance. One new megawatt of CST

hardware was installed worldwide in 2006; in 2007 there were 100. The Earth Policy Institute projects that the installation of CST worldwide will double every 16 months, from 457 megawatts in 2007 to 6,400 megawatts by 2012. At least 13 plants are in advanced planning stages in the U.S.

eSolar’s approach is comparatively cheap because, unlike most of its competitors, which use large, custom-built parabolic mirrors to capture sunlight from all angles, eSolar uses small, flat mirrors, each about the size of a big-screen television. Computerized tracking keeps each mirror focused at the optimal angle throughout the day. The mirrors are easy to manufacture, and it takes just two workers to attach them to relatively light scaffolding on-site. ESolar’s standard 46-megawatt array, which makes enough juice to power about 30,000 homes, occupies only a quarter of a square mile, which will allow the company to avoid the land-use fights that have ensnared other solar companies.

Sierra is a demonstration project, but in February eSolar signed a deal to build 11 46-megawatt plants in the Southwest, and it is set to build a full gigawatt’s worth of plants in India. “Efficiency wins in every industry,” Gross says, “and it’s going to win in solar as well.”—DAVID ROBERTS



ELECTRICAL FIELD The Google-funded start-up eSolar uses computer tracking to keep thousands of mirrors like the ones in this illustration focused on boilers sitting atop towers. The light heats the water to 850°F, creating steam that turns a turbine and generates electricity.

WIND POWER

THE BIG PICTURE Wind power is all about location—getting turbines where the breeze blows steady and strong. One of the best places for that is far out at sea. And because one of the biggest obstacles to expanding wind power is overcoming the objections of residents who don't want wind farms blocking their views, deepwater wind, which is invisible from shore, has dual appeal.

WHERE WE ARE: **94 GW** WHAT WE NEED BY 2050: **2,000 GW**

VIRGIN WATERS The Hywind project aims to perfect technology for floating windmills in the deep ocean, opening up new room for wind power to breathe.



TECH TO WATCH: DEEPWATER WIND

According to the U.S. Department of the Interior, seabound wind farms off the Pacific coast could generate 900 gigawatts of electricity every year. Unfortunately, the water there is far too deep for even the tallest windmills to touch bottom. An experiment under way off the coast of Norway, however, could help put them anywhere.

The project, called Hywind, is the world's first large-scale deepwater wind turbine. Although it uses a fairly standard 152-ton, 2.3-megawatt turbine, Hywind represents "totally new technology," says Walter Musial, the principal engineer for ocean renewable energy at the National Renewable Energy Laboratory of the U.S. Department of Energy. The turbine will be mounted 213 feet above the water on a floating platform, or spar—a technology Hywind's creator,

the Norwegian company StatoilHydro, draws from its experience as Scandinavia's largest gas and oil company. The steel spar, which is filled with ballast and extends 328 feet below the sea surface, will be tethered to the ocean floor by three cables; these will stabilize the platform and prevent the turbine from bobbing excessively in the waves. Hywind's stability in the turbulent, wintry Scandinavian sea would prove that even the deepest corners of the ocean are suitable for wind power. If all goes according to plan, the turbine will start generating electricity six miles off the coast of southwestern Norway as early as September.

To produce electricity on a large scale, a commercial wind farm will have to use bigger turbines than Hywind does, but it's difficult enough to balance such a large turbine so high on a floating pole in the middle of the

ocean. To make that turbine heavier, the whole rig's center of gravity must be moved much closer to the ocean's surface. To do that, StatoilHydro plans to engineer a new kind of wind turbine, one whose gearbox (the mechanism that transfers power between the rotor and the generator) sits at sea level rather than behind the blades.

Hywind is a test run, but the payoff for perfecting floating wind-farm technology could be enormous. Out at sea, the wind is often stronger and steadier than close to shore, where all existing offshore windmills are planted. Deep-sea farms are invisible from land, which helps overcome the windmill-as-eyesore objection that has derailed wind farms in the past. If the technology catches on, it will open up vast swaths of the planet's surface to one of the best low-carbon power sources available.—H.R.

OUR BODIES, OUR HOLODECKS

WHAT CAVEman, a virtual-reality rig that simulates the anatomy and physiology of the human body

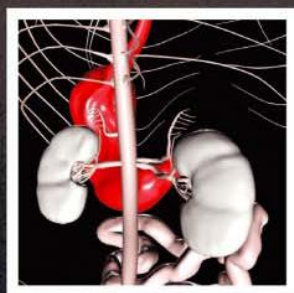
WHERE Alberta, Canada

WHY Because the world needs a more affordable, less invasive alternative to body scans

WOW Hit zoom to see a blood cell eight feet wide.

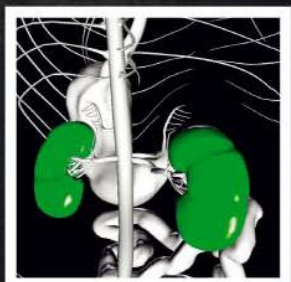
WHAT HAPPENS when you pop a pill? Inside the University of Calgary's \$1.5-million virtual-reality room, scientists can don a pair of 3-D goggles and find out in high-definition detail. Biochemist Christoph Sensen and his colleagues have created a virtual human dubbed the CAVEman (for Automated Virtual Environment) that lets them monitor how a virtual body metabolizes medicine. In this image, three stereoscopic projectors mounted on the floor and one on the ceiling display a computer-animated body. Looking

through the goggles, researchers can watch its bloodstream turn from white to red as aspirin travels through it. Sensen hopes to develop computer simulations that will model the progression of diseases like Alzheimer's and diabetes and help scientists quite literally look for cures. Updated to reflect what's happening inside a real patient, the technology could also help doctors diagnose and treat cancer. "You could stand inside your patient," Sensen says, "and see how big the tumor is, how to treat it, and what the outcome will be."



ASPIRIN IN ACTION

The virtual-reality rig at the University of Calgary visualizes aspirin's journey through the body in 3-D. First stop: the stomach and intestines [red], where the drug is absorbed. Next up is the bloodstream [light green] and finally the kidneys [dark green], which flush by-products into the urine.



COURTESY CHRISTOPH SENSEN; INSETS: COURTESY SUN CENTER OF EXCELLENCE FOR VISUAL GENOMICS; PRECEDING PAGES: COURTESY SUGANO LABORATORY/WASEDA UNIVERSITY; FACING PAGE: JOHN B. CARNETT

DEAD MAN FLOATING Christoph Sensen designed this 3-D virtual patient to simulate more than 3,000 body parts.



CUT-BY-COLOR SURGERY

WHAT Fluorescence-Assisted Resection and Exploration, a new technique that makes cancerous tissue glow during surgery, one cell at a time

WHERE Boston

WHY Of the 1.5 million cases of cancer diagnosed annually, nearly all of them require surgery.

WOW Pinpoints the spread of cancer in seconds

THE BEST WAY to stop a tumor from spreading is to simply cut it all out. The tricky part is to do that without damaging healthy tissue. Now oncologist John Frangioni at Beth Israel Deaconess Medical Center in Boston has invented a technique that lights up tumorous tissue like a neon sign and sets it off from non-cancerous tissue. It's called FLARE, for Fluorescence-Assisted Resection and Exploration, and it works a bit like a multicolored highlighter for surgeons.

In the operating room, the physician injects a patient's tumor with dyes that tag lymph fluid and

glow when exposed to near-infrared light. The \$150,000 FLARE device has three infrared cameras, each calibrated to pick up different frequencies of light. On a video screen, the nerves to be avoided appear fuchsia, while a bright green shines from the tumor and outlines its drainage path to the sentinel lymph nodes—those most likely to collect cancer cells.

Frangioni and a colleague at Beth Israel Deaconess, surgeon Susan Troyan, are currently enrolling about 50 breast-cancer patients in the largest clinical trial of FLARE yet.

STEP 1: INJECT DYE To map lymph nodes in a pig, doctors start by injecting a contrasting agent into its hind leg.



STEP 2: ADD LIGHT The dye flows through the pig's lymphatic system and glows bright green on a monitor when exposed to near-infrared light.



STEP 3: REMOVE TISSUE Using the monitor as a guide, the surgeon cuts out the target lymph node, sparing the unlit healthy tissue around it.



CONCEPTS & PROTOTYPES

WHERE TOMORROW'S TECHNOLOGY BEGINS

HANG TIME *Odysseus* would mainly circle above stationary targets for long periods of time, but it is capable of long-distance flight and therefore could be redeployed—slowly—to other sites around the world.

FULL EXPOSURE When the sun is low on the horizon, the aircraft's Z-wing configuration allows solar cells to catch more rays. It flattens at night for more-aerodynamic flying.

THE FOREVER

Nine days: That's the longest any airplane has stayed in the air. Burt and Dick Rutan's *Voyager* set the record in 1986 by flying 24,986 miles around the world without refueling. But nine days of uninterrupted flight won't cut it for Darpa, the Pentagon's advanced-research organization. It's challenged the aviation industry to come up with an unmanned surveillance and communications plane that can circle targets for half a decade—and do so on nothing but solar power.

The aircraft you see here, *Odysseus*, was the first entry in the Vulture program, the competition Darpa created to make its extreme-endurance dreams come true. If the plane's

designers at Aurora Flight Sciences beat rival entries by Boeing and Lockheed—Darpa could pick a winner as early as this year—it will have the opportunity to make this concept into the real thing: a 492-foot-wide folding aircraft that can cruise at 140 mph at 70,000 feet for five years straight, powered by the solar panels that cover the top of the plane.

In fact, *Odysseus* is three planes in one, a collection of 164-foot-long wing-shaped constituent aircraft that take off separately and dock in the stratosphere, where the air is calmer and less stressful on the massive structure. (Aurora CEO John Langford says the company hasn't chosen a docking mechanism yet but that it's considering something based on



SUM OF ITS PARTS Three constituent vehicles, each 164 feet long, will dock in midair to form a larger aircraft. Each is capable of controlling the entire vehicle using its three electric-motor-driven propellers.

ODYSSEUS, AN AUTONOMOUS SURVEILLANCE-PLANE CONCEPT, WILL FLY FOR YEARS ON END, POWERED BY NOTHING BUT THE SUN

BY KARA PLATONI ILLUSTRATION BY JOHN MACNEILL

PLANE

the system that connected NASA's Apollo command and lunar modules.) Each piece is interchangeable and can be swapped out in midair for repairs or upgrades. The three-piece construction allows *Odysseus* to autonomously change shape throughout the day to trap as much solar energy as it can. It could pleat like an accordion into a "Z" to absorb sunlight at low angles—at dusk, for example—and flatten into a more aerodynamically efficient traditional wing at night.

Catching as much sun as possible is essential, because energy—specifically, energy storage—is one of the biggest obstacles to solar flight, particularly solar flight that must continue without fail for years on end. Langford says Aurora is

exploring storage methods, including flywheels, fuel cells and an array of batteries embedded throughout the airframe. The plane also needs to be light, so Aurora's design relies on featherweight carbon composites. The huge craft could weigh in at under 7,000 pounds—approximately 2,000 pounds less than a fully fueled *Voyager*, which was less than a quarter of *Odysseus*'s size.

Although it's designed to be a surveillance platform, the lanky *Odysseus* would probably appear to the naked eye as a starlike glint, so it could be used for less-covert missions, such as patrolling a border or watching over suspected nuclear-reactor sites. And it could have civilian applications: Langford imagines it as an atmospheric buoy, monitoring storm development, climate change or the health of the ozone layer. Either way, he says, it would demonstrate the potential of solar power and serve as a testbed for green aircraft technology. "If we can build an airplane that can stay up for five years with nothing but sunlight," he says, "what else can we do?"

DISASTER CITY P.46

Inside the Ultimate Catastrophe-Training School

ROBOT FARMERS!

And 7 Other High-Tech Ways to Feed the World P.38

POPULAR SCIENCE

**25 HOT
PRODUCTS**

P.13



It's a
Keyboard
and a Computer!

THE
FUTURE
NOW

SECRETS OF THE DEEP

Exploring the Untouched Oceans with
a New Generation of Manned Subs P.32

EXPOSED:
WE DEBUNK
BOGUS
HEALTH NEWS P.54



US \$4.99

AUGUST 2009



08



CONTENTS

THIS MONTH'S GUIDE TO INNOVATION AND DISCOVERY

AUGUST '09

VOLUME 275 #2

FEATURES



● CONCEPTS & PROTOTYPES

32 **ANOTHER LEAGUE UNDER THE SEA**

A new generation of manned submersibles will soon open up 98 percent of the world's oceans to human eyes by diving more than 20,000 feet into the ocean. Fresh energy sources, new species—who knows what we'll find in Earth's last unexplored frontier?

By Abe Streeb

● THE FUTURE OF FARMING

38 **8 SOLUTIONS FOR A HUNGRY WORLD**

To feed a ballooning population despite shrinking farmland, every acre will have to count. Here's the tech that will turbocharge harvests, including desert cultivation tricks, bacteria that fertilize crops, and fruit-picking robots.

By Hillary Rosner

● FIELDWORK

46 **DISASTER IN THE MAKING**

What the largest search-and-rescue training facility is teaching us about surviving catastrophe. By Lisa Taddeo

● THE GREEN DREAM

54 **A SOLAR-POWERED BOILER**

Learn from PopSci's staff photographer as he constructs an eco-friendly and affordable home. This month: solar-powered hot water.

By John B. Carnett



56



● UNCOMMON KNOWLEDGE

56 **OVERHYPED HEALTH HEADLINES REVEALED**

Does red wine make you live longer? Does bacon cause cancer? We uncover what scientific studies really mean for your health.

By Jason Daley

ON THE COVER: NICK KALOTERAKIS; THIS PAGE, CLOCKWISE FROM TOP: NICK KALOTERAKIS; STOCK; JOHN B. CARNETT; BRENT HUMPHREYS; PAUL WOOTTON

WHAT'S NEW

TECH THAT PUTS THE FUTURE IN THE PALM OF YOUR HAND



17

Full-fledged electric cars finally hit the road



18

A personal watercraft that's speedy and safe



20

Cellphones that turn you into an artist

ASUS EEE KEYBOARD

PROCESSOR: Intel Atom 1.6-gigahertz

STORAGE: 16-gigabyte solid-state drive

OPERATING SYSTEM: Windows XP Home

BATTERY LIFE: 1.5 hrs.

SIZE: 16.6 x 5.5 x 0.75 in.

PRICE: \$500-\$600 (est., and some specs may change; available Sept.)

GET IT: usa.asus.com

MASTER KEYS

A KEYBOARD THAT'S ACTUALLY A COMPUTER

Go ahead, cancel your cable. Asus's new keyboard is the first to hide an entire Windows PC inside, plus a wireless connection that turns your TV into its monitor. Just park yourself on the couch, choose your favorite show from a site like *Hulu.com* or iTunes, and watch *Lost* play in full glory on your living-room screen.

Asus makes this freedom possible by giving the keyboard the same small circuit board—about three by three inches—as its Eee netbook, a mini budget laptop. The Eee keyboard will be among the first gadgets with a radio chip that beams high-definition video, and it comes with a receiver that you can plug into any

TV in your house, up to 15 feet away.

The keyboard even has a 5.5-inch touch-sensitive display of its own, which lets you scrawl notes by hand. Or, now that you've gotten rid of the cable company's channel guide, use the display to browse the Web for whatever sitcom you'll veg out to next.—LAUREN AARONSON

BRIAN KLUTCH

WHAT'S NEW

CONTROL DECK

In Tony Hawk's new videogame, you maneuver a wheelless skateboard that's just like a real one, only safer. Accelerometers gauge tilt and rotation; infrared motion sensors on the sides detect your foot kicking the floor. **Activision Tony Hawk: Ride** Price not set; thride.com



GO WITH THE FLOW

Change this showerhead's spray from gentle to pounding by flipping its face. Each of its two wide sides and two narrow edges has a different nozzle pattern. As it turns, spring-loaded valves inside direct water to only the side that points downward. **Kohler Flipside** \$110; kohler.com



THE GOODS

12 MUST-HAVE PRODUCTS

BY AMANDA SCHUPAK

HOLLYWOOD AT HOME

Make yourself a movie star with Yoostar's green screen, camera and software. The system digitally removes characters from classic film clips, fills in missing backgrounds, and splices in your image to create a seamless result. **Yoostar** \$170; yoostar.com



THE EASY WAY

The Out&Back GPS unit makes it simple to load the routes that many hikers post online. It automatically recognizes a standard map format, called GPX, so you can drag files from your computer to the device without special conversion software. **Lowrance Endura Out&Back** \$300; www.lowrance.com



TRANSISTOR RADIO 2.0

A smaller, lower-power receiver chip makes this the first portable radio to get digital broadcasts. It can tune in, static-free, to the many available HD Radio stations and runs for 10 hours on a charge. **Insignia HD Radio Portable Player** \$50; bestbuy.com

RIGHT ANGLERS

Fly-fishermen unwittingly spread invasive species from stream to stream when their felt-soled boots, meant for traction, absorb algae. Simms uses a tacky rubber that hangs onto riverbeds but not gunk. **Simms Guide Boot StreamTread** \$200; simmsfishing.com



ANOTHER LEAGUE UNDER THE SEA

ARMED WITH BETTER BATTERIES AND STRONGER MATERIALS, NEW SUBMERSIBLES AIM TO GO DEEPER THAN EVER BEFORE AND OPEN THE WHOLE OF THE UNEXPLORED OCEAN TO HUMAN EYES

BY ABE STREEP

BY LIBERAL ESTIMATES, we've explored about 5 percent of the seas, and nearly all of that in the first 1,000 feet. That's the familiar blue part, penetrated by sunlight, home to the colorful reefs and just about every fish you've ever seen. Beyond that is the deep—a pitch-black region that stretches down to roughly 35,800 feet, the bottom of the Marianas Trench. Nearly all the major oceanographic finds made in that region—hydrothermal vents and the rare life-forms that thrive in the extreme temperatures there, sponges that can treat tumors, thousands of new species, the *Titanic*—have occurred above 15,000 feet, the lower limit of the world's handful of manned submersibles for most of the past 50 years.

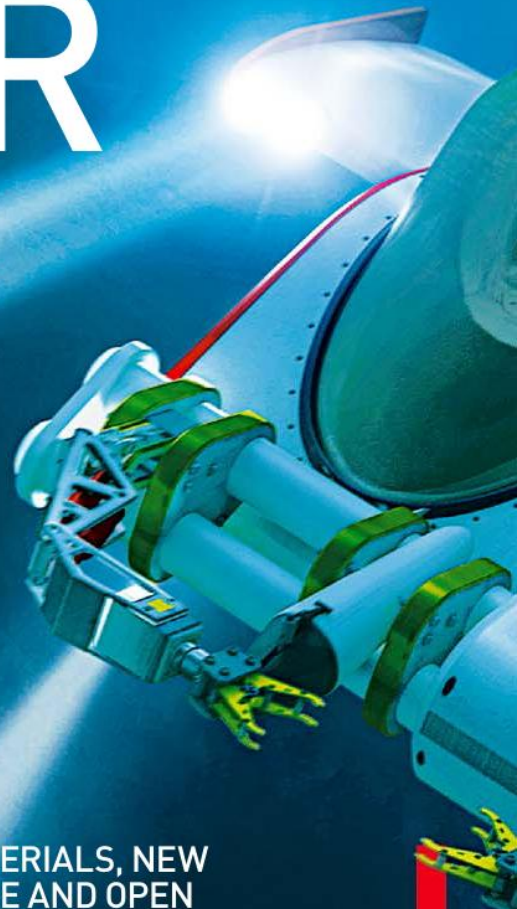
Now engineers want to unlock the rest of the sea with a new fleet of manned submersibles. And they don't have to go to the very bottom to do it. In fact, only about 2 percent of the seafloor lies below 20,000 feet, in deep, muddy trenches. If we extend our current reach just 5,000 feet—another mile—it will open about 98 percent of the world's oceans to scientific eyes.

The payoffs could be huge. Mining companies hope to search hydrothermal vents for minerals like nickel; gas and oil companies are eager to explore the seafloor for new energy sources; and marine biologists want to study how climate change has affected deep ecosystems. In addition, there's simple curiosity of the man-versus-

nature sort. With all the world's highest peaks summited and both poles trampled, the deep seas are a ripe frontier.

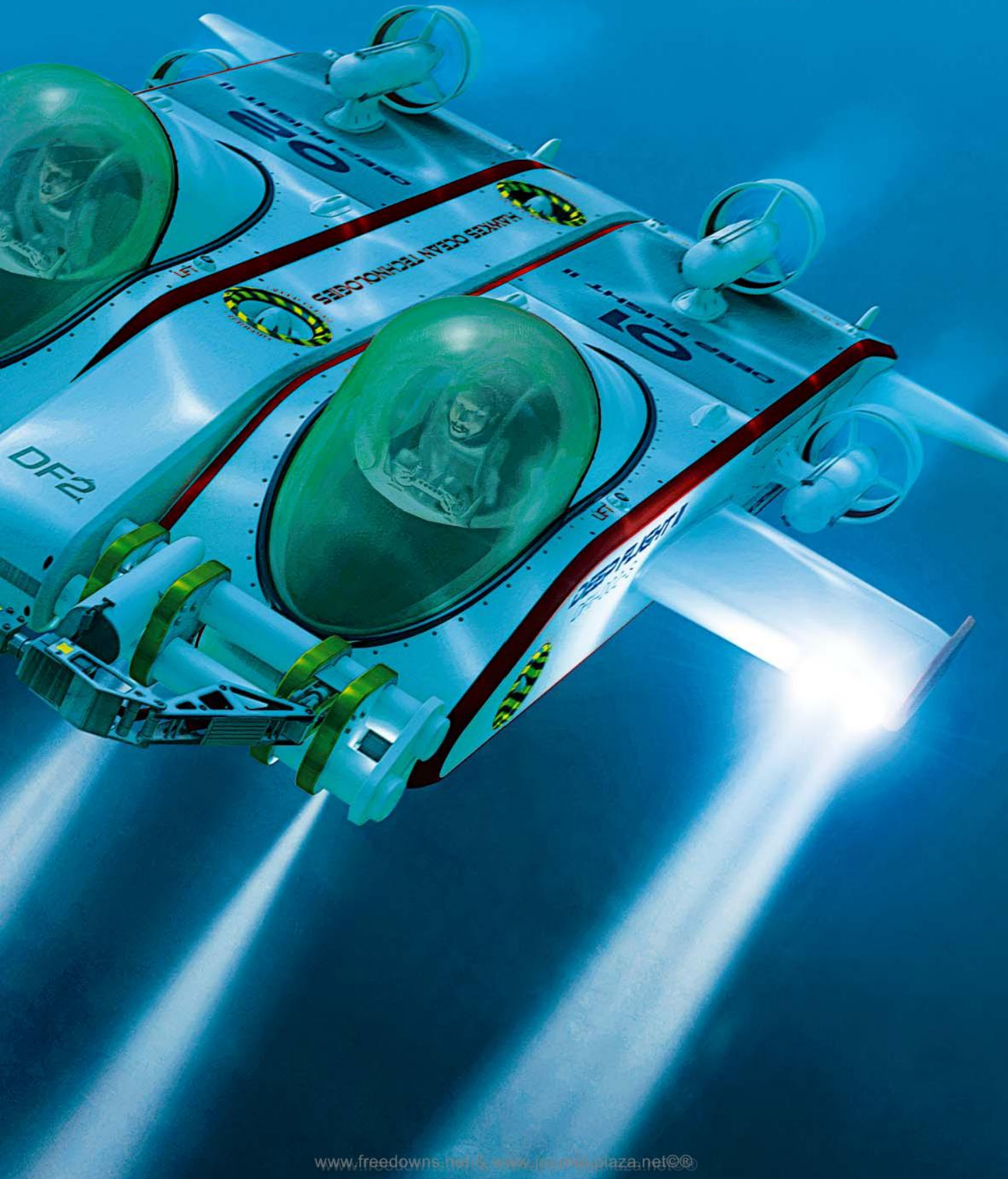
But sending a vehicle that deep requires serious cash and engineering. The craft must be small enough to move on battery power and sturdy enough to withstand immense pressure—10,340 pounds of water per square inch at 23,000 feet, equivalent to having a school bus on your head. A manned submersible has to meet even higher standards: It must keep its occupants alive.

In 1960, American naval lieutenant Don Walsh and Swiss engineer Jacques Piccard made the only expedition to the world's deepest point, piloting a 50-foot, submarine-like vehicle called the



NICK KALOTERAKIS

FLYING LOW The *Deep Flight II* sub uses stubby wings that propel it down like an airplane goes up.



THE SCIENCE SUB

A new *Alvin* sub—a complete \$21-million retooling of the 45-year-old workhorse of deep-sea research—should be complete by 2015, with a new body and lighter batteries that will let it go deeper (21,000 feet), stay down longer (10 hours), and rise 50 percent faster, at 1.78 miles an hour.—MARSHALL LOUIS REAVES

LIGHTS

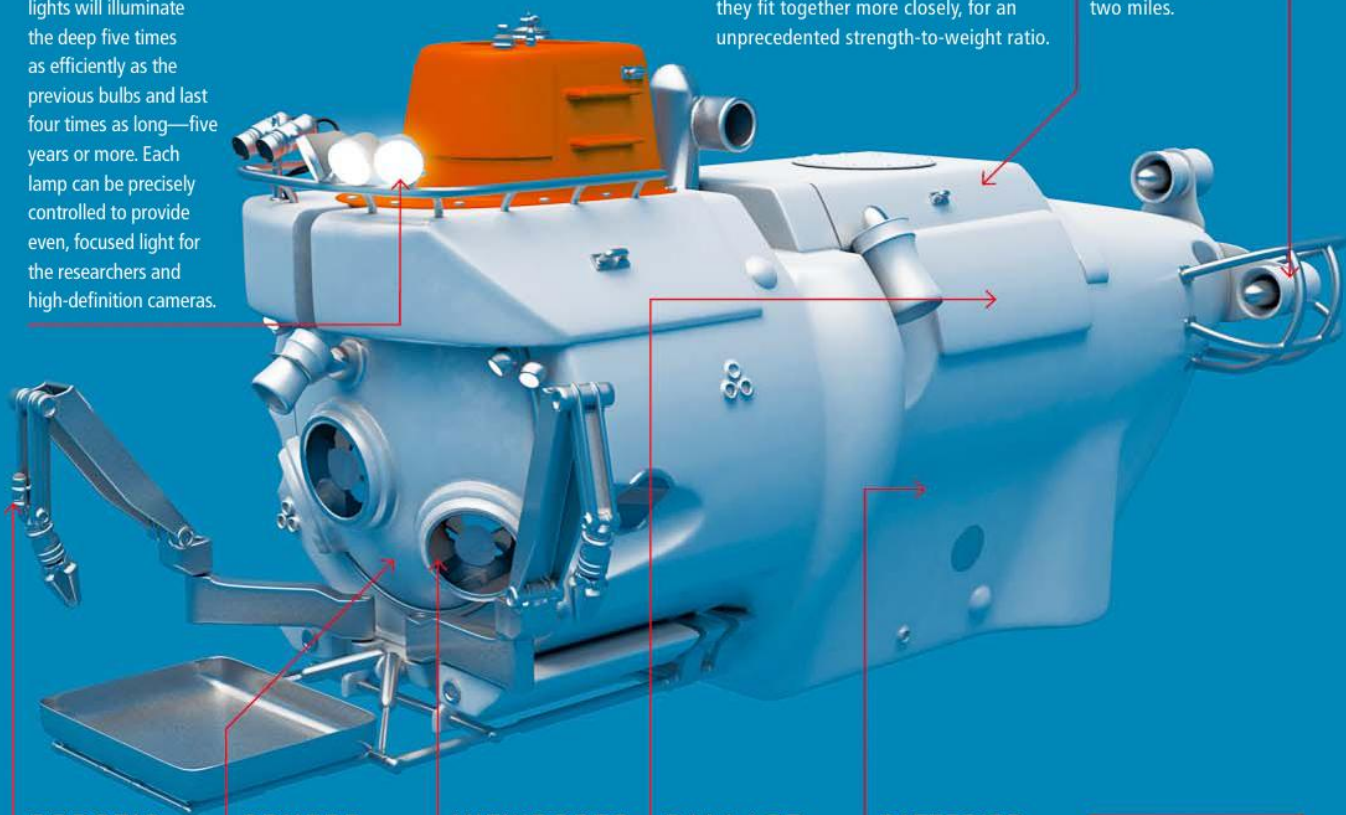
Ten bundles of LED lights will illuminate the deep five times as efficiently as the previous bulbs and last four times as long—five years or more. Each lamp can be precisely controlled to provide even, focused light for the researchers and high-definition cameras.

BODY

The body is kept afloat by a material called syntactic foam, which consists of billions of tiny air-filled glass spheres embedded in an epoxy resin, like hardened Styrofoam. Syntactic foam has been used in oil rigs and diving equipment, but *Alvin* will employ a new version that combines two different sizes of glass spheres, which means they fit together more closely, for an unprecedented strength-to-weight ratio.

THRUSTERS

Six electric thrusters let the craft move in any direction. The typical range is only a few hundred yards, but if there's nothing else being powered by the batteries, *Alvin* could travel up to two miles.



ROBOTIC ARMS

The new *Alvin* gets a more powerful and agile set of robotic arms, and its basket can carry up to 400 pounds of equipment or samples to and from the surface. Its tool arsenal includes sensors for measuring thermal vents and coring devices for sampling sediments.

SPHERE

Forged from a strong yet lightweight titanium alloy, the seven-foot-diameter crew sphere is machined with exacting precision. Discrepancies of even $\frac{1}{50}$ of an inch from a perfect sphere could cause a structural collapse under the intense pressure of the deep ocean.

VIEWPORTS

Five viewports—two more than the current sub and, at more than a foot across, several inches larger—let researchers view wider swaths of the deep through nearly four inches of Plexiglas. The new array lets the pilot look left and right from the driver's seat without getting up.

BALLAST

Steel weights carry *Alvin* toward the bottom. A ballast system adjusts buoyancy once it reaches the bottom and unloads some of its equipment, releasing air from fiberglass tanks to help it stay down. To ascend, the pilot just releases the steel weights.

BATTERIES

The biggest upgrade is a cadre of lithium-ion batteries, which provide twice the power at half the weight of the old lead-acid batteries. They will enable dives of more than 10 hours (five hours longer than today's *Alvin*) and a top speed of three knots, up from the current two.

STATS

ALVIN

SIZE: 24 ft. long x 9 ft. wide x 12 ft. high (est.)
WEIGHT: 20 tons
OPERATING TIME: 10.5 hrs.
CREW: 1 pilot, 2 researchers
MAX. DEPTH: 21,000 ft. (by 2015)
VERTICAL SPEED: 157 ft./min.

THE UNDERWATER PLANE

Graham Hawkes wants to create a comparatively affordable deep-sea sub that's light enough to launch from a yacht and easy to drive, opening the depths to an army of private explorers. His winged craft will operate solo or in pairs and travel miles along the seafloor. —M.L.R.

COCKPIT

The pilot, strapped in stomach-down, can steer the craft using a joystick to control the wings. The prone position mirrors the natural posture of divers and fish and puts the pilot's eyes as close as possible to the viewport and the robotic arms. It also minimizes the size of the pressurized chamber, which reduces the craft's weight to just 5,000 pounds.

BATTERIES

Hawkes is using the latest lithium-ion batteries, known as lithium-polymer. Their housing is pressurized to help with buoyancy.

BODY MATERIALS

Developed by the U.S. Navy and refined by Hawkes's team, the composite ceramics of the body tout a higher strength-to-weight ratio than titanium. The body surrounds the pressurized hull and other equipment, like the battery cells.



THRUSTERS

In a "work" configuration, four pairs of lateral and hovering electric thrusters—five-bladed propellers—allow for careful maneuvers near the seafloor, stabilizing the craft within fractions of an inch for hovering against cliff faces. Configured for sight-seeing, two high-speed thrusters propel the sub forward at 600 feet per minute.

WINGS

Two stubby wings allow the sub to "fly" underwater in any direction. Rather than slowly sinking or rising like a blimp, the craft uses water running past its wings to create reverse lift—the opposite of the force on an airplane's wings—and moves up or down depending on the position of the flaps. It can dive 400 feet per minute, four times as fast as current subs.

LIGHTS AND CAMERAS

Wing- and nose-mounted LED lamps let the pilot and the onboard high-definition cameras see 40 feet into the inky black. Lasers probe the water for obstacles ahead, while low-intensity sonar scans the water for creatures so the pilot can quickly turn on the lights and snap a photo before the animal darts away.

HULL

A cylindrical compartment needs to be twice as strong as a spherical one because of the way the pressure is distributed over the surface of the pressurized hull. Hawkes is using a special kind of carbon composite, originally developed for aerospace applications like rocket nozzles, that better resists compression than standard carbon fiber, which is best at resisting tearing. Traditionally, carbon fiber is made with an interwoven pattern that makes for weak spots where the fibers overlap. To make the new material, a computer lays each braided, hair-size fiber alongside the next. The carbon composite is lighter than titanium, which aids buoyancy.

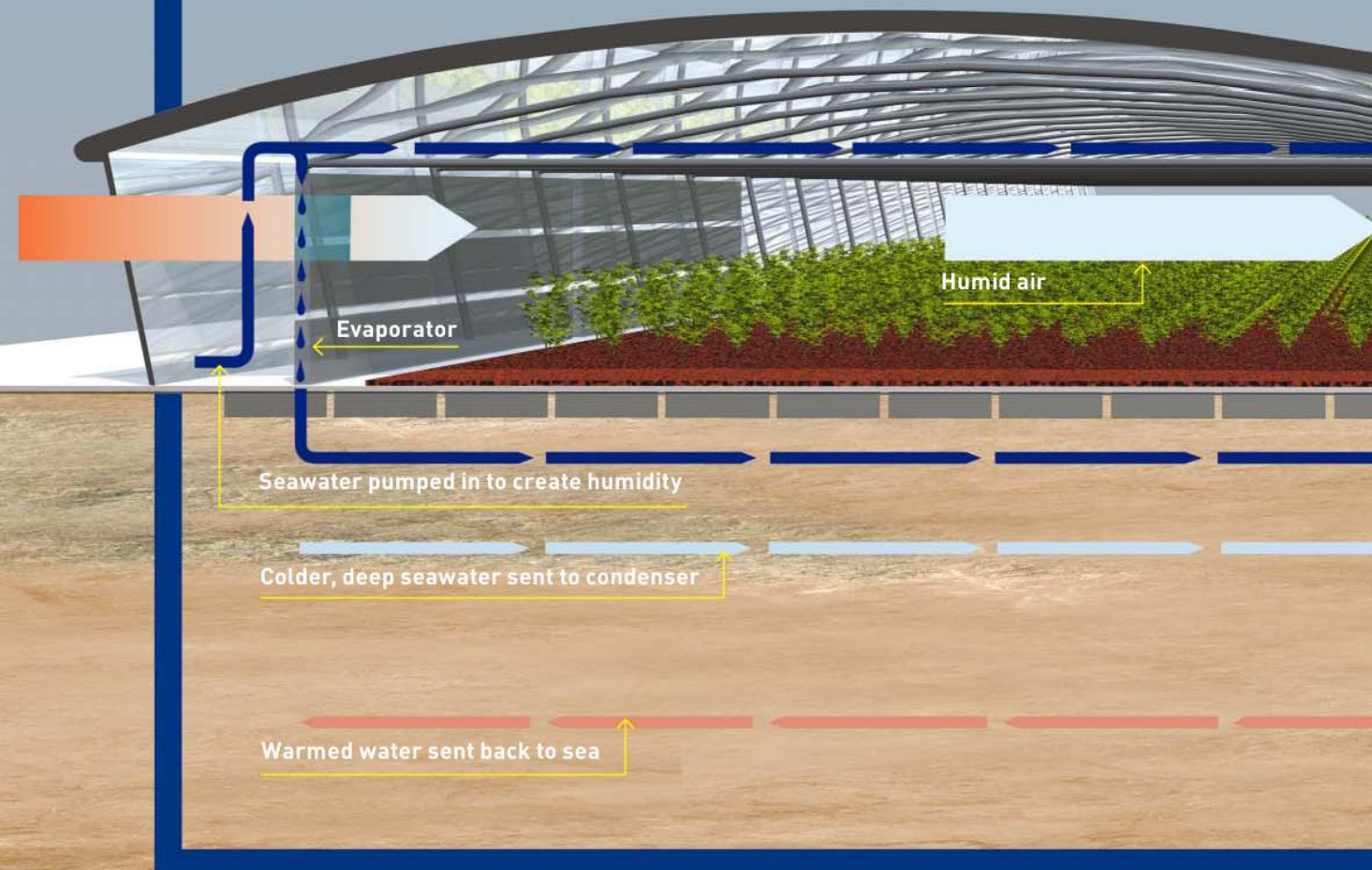
STATS

DEEP FLIGHT II

SIZE: 16 ft. long, 4.5 ft. wide, 4 ft. high
WEIGHT: 5,000 lbs.
OPERATING TIME: 8 hrs.
CREW: One- and two-person configurations
MAX. DEPTH: Initially 6,500 ft., eventually 35,800 ft.
VERTICAL SPEED: 500 ft./min. ascent, 400 ft./min. descent

8 SOLUTIONS FOR A HUNGRY WORLD

Today's crops crisscross the globe: Mexico's tomatoes end up on your plate, our wheat heads to Africa. As a result, the challenge of growing twice as much food by 2050 to feed nine billion people—with less and less land—is everyone's problem. But scientists are hard at work fomenting a second green revolution. Here's how nitrogen-spewing microbes, underground soil sensors and fruit-picking robots will help keep food on our tables. BY HILLARY ROSNER ILLUSTRATIONS BY PAUL WOOTTON



1 FARM THE DESERT

70%: Amount of the world's freshwater used for agriculture

SOLUTION Greenhouses built near coasts turn plentiful seawater into freshwater for crops, without expensive desalinization plants.

POTENTIAL Farmers could grow cash crops like lettuce and tomatoes in the desert.

ETA Three pilot projects are under way, and researchers are scouting sites for a larger full-scale project.

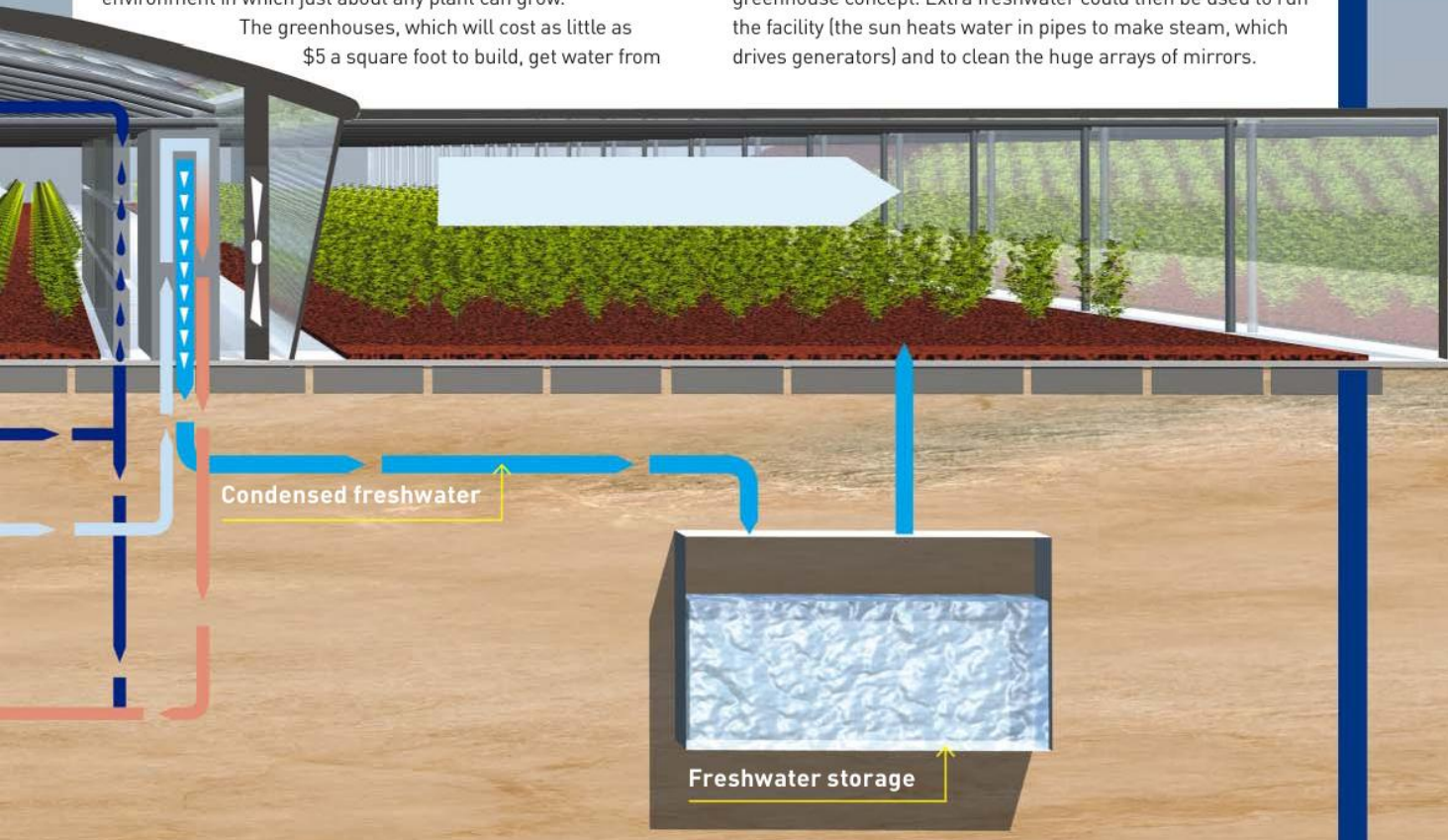


On frequent trips to Morocco, British lighting designer Charlie Paton was struck by the juxtaposition of sea and vast, sweeping desert. "You're on the edge of the Sahara but so close to the ocean," he says. After selling his lighting company, Paton set about designing something that brings the two together: the Seawater Greenhouse, a low-energy means of growing food in desert regions using abundant nearby saltwater. Three pilot greenhouses in Tenerife, the Canary Islands; Abu Dhabi, the United Arab Emirates; and Oman use prevailing winds, fans and simple evaporators to convert seawater into fresh, and in the process create a humid environment in which just about any plant can grow.

The greenhouses, which will cost as little as \$5 a square foot to build, get water from

the sea, either by gravity or a pump. The water trickles down honeycomb-shaped lattices on the front wall and evaporates, cooling and humidifying the air inside. The air warms as it travels across the greenhouse—hotter air can hold more moisture—before reaching a second evaporator, which supersaturates it. From there, the air moves immediately into a condenser, which pulls out freshwater and sends it to an underground storage tank for watering the plants.

Paton is now scouting locations for the Sahara Forest Project, which will add a "concentrating solar power" plant to the greenhouse concept. Extra freshwater could then be used to run the facility (the sun heats water in pipes to make steam, which drives generators) and to clean the huge arrays of mirrors.



CYBORG SPY-BUGS!

Terrifying Science or Innocent Research? p.52

THE MIND READERS

Scientists Who Can Pluck Images from Your Head p.58

POPULAR SCIENCE

THE
FUTURE
NOW

**34 HOT
PRODUCTS**

p.21



A Robo-Vac with
Laser Vision

REBUILDING AMERICA

25 New Technologies to
Transform Our Crumbling
Infrastructure p.38



FEBRUARY 2010

\$5.99

ANNOTATED MACHINE

READY, AIM, RESUPPLY

A GIANT CANNON DESIGNED TO BLAST SUPPLIES INTO SPACE ON THE CHEAP

John Hunter wants to shoot stuff into space with a 3,600-foot gun. And he's dead serious—he's done the math. Making deliveries to an orbital outpost on a rocket costs \$5,000 per pound, but using a space gun would cost just \$250 per pound.

Building colossal guns has been Hunter's pet project since 1992, when, while a physicist at Lawrence Livermore National Laboratory, he first fired a 425-foot gun he built to test-launch hypersonic engines. Its methane-driven piston compressed hydrogen gas, which then expanded up the barrel to shoot a projectile. Mechanical firing can fail, however, so when Hunter's company, Quicklaunch, released its plans last fall, it swapped the piston for a combustor that burns natural gas. Heat the hydrogen in a confined space and it should build up enough pressure to send a half-ton payload into the sky at 13,000 mph.

Hunter wants to operate the gun, the "Quicklauncher," in the ocean near the equator, where the Earth's fast rotation will help slingshot objects into space. A floating cannon—dipping 1,600 feet below sea level and steadied by a ballast system—would let operators swivel it for different orbits. Next month, Hunter will test a functional, 10-foot prototype in a water tank. He says a full-size launcher could be ready in seven years, provided the company can round up the \$500 million. Despite the upfront cost, Hunter says he has drawn interest from investors because his reusable gun saves so much cash in the long haul. Just don't ever expect a ride in the thing: The gun produces 5,000 Gs, so it's only for fuel tanks and ruggedized satellites. "A person shot out of it would probably get compressed to half their size," Hunter says. "It'd be over real quick."

—AMINA ELAHI

HOW TO SHOOT STUFF INTO SPACE

STEP 1: HEAT IT

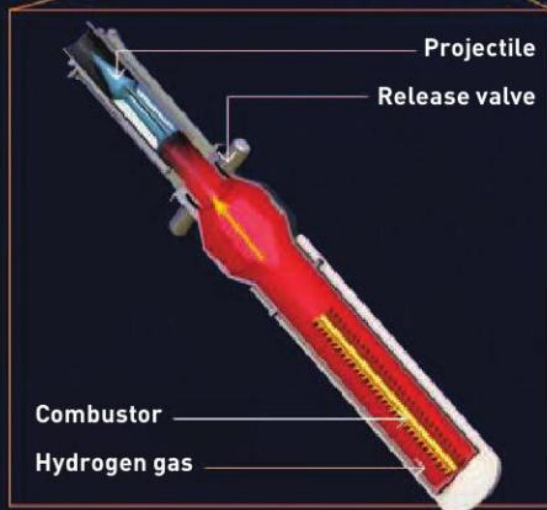
The gun combusts natural gas in a heat exchanger within a chamber of hydrogen gas, heating the hydrogen to 2,600°F and causing a 500 percent increase in pressure.

STEP 2: LET THE HYDROGEN LOOSE

Operators open the valve, and the hot, pressurized hydrogen quickly expands down the tube, pushing the payload forward.

STEP 3: TO INFINITY AND BEYOND

After speeding down the 3,300-foot-long barrel, the projectile shoots out of the gun at 13,000 mph. An iris at the end of the gun closes, capturing the hydrogen gas to use again.



JOHN MACNEILL

➤➤➤ **JANUARY 4** The U.S. government stops a 22-year ban on HIV-positive immigrants and drops HIV testing from the required medical exam. ➤➤➤

WHAT'S NEW

WALKING ON AIR

These boots keep pressure off your heels. Their polyurethane midsoles are injected with air to absorb nearly one third more shock than other boots. **Scarpa Mont Blanc GTX** \$420; scarpa.com



LIGHT MUSIC

Finally, multi-room audio is as easy as screwing in a lightbulb. This system hides speakers behind LEDs made to fit into any fixture, including recessed ceiling sockets, and wirelessly streams your tunes. **Klipsch LightSpeaker** \$600; klipsch.com



THE GOODS

A DOZEN GREAT IDEAS IN GEAR

BY CORINNE IOZZIO

SHOW OFF

Rather than add the bulk of an onboard projector, a pico projector add-on snaps onto the LG eXpo like a backpack and beams an image of up to 60 inches diagonal onto any surface. **LG eXpo with Mobile Projector** \$480; lge.com



POWER DOWN

A laptop's power brick sends juice even when the device isn't running. iGo's adapter has a computer chip that knows when a notebook is idle, so it will stop sipping wattage when it doesn't need it. **iGo Green Laptop Charger** \$100; igo.com



MINI MECHANIC

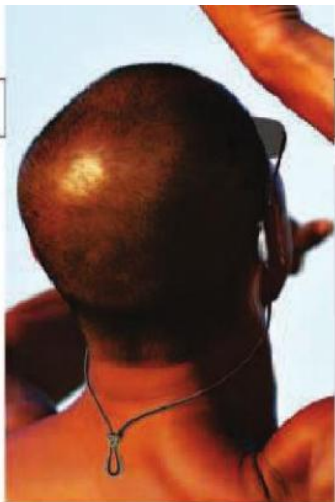
The ecoRoute keeps tabs on your engine. The 3.5-ounce dongle connects to a car's diagnostic port to send info about things like fluid levels to an app on a GPS or phone via Bluetooth. **Garmin ecoRoute HD** \$150; garmin.com



DOGFIGHT SIMULATOR

The Drone robot turns real life into a videogame. Through its iPhone app, you see what it sees, and the software turns real-life objects like trees and rocks into targets you shoot (virtually) to up your score. **Parrot AR Drone** Price not set; parrot.com





SMALL TALK

The Sound Band is the most discreet Bluetooth headset you can find. Its stereo receivers thread onto the back of your glasses, and micro-vibrations from them turn your ears into speakers only you can hear.

Hybra Sound Band
\$100; hybratech.com

STORE MORE

LG's Blu-ray player is the first to add storage and let you save streaming video. Its 250-gig hard drive holds 32 high-def flicks from the Vudu service or your library. **LG BD590** Price not set; lge.com



BOOK BROWSER

The eDGe is the first e-reader to give you a full Web experience on its second, 10-inch LCD. For instance, video links on the E Ink side jump to its extra, faster screen. **enTourage eDGe** \$490; entourageedge.com



NIGHT WATCH

This clock does more than wake you up; it also tracks your sleep cycle. Together with its iPhone app, the iA5 keeps a log based on when you tuck in and wake up, so you'll know if you're short on zzzs. **iHome iA5** \$100; ihomeaudio.com



LAP TOPPER

When watching a DVD on your computer, this lap desk helps it sound *and* run better. The cushion has speakers and a vented chamber to let bass resonate, while a fan keeps things cool. **Logitech Speaker Lapdesk N700** \$80; logitech.com



FACE-TO-FACE

This cellphone is the first in the U.S. to handle two-way video calls. Simply face the lens and speak normally, and the Saygus software makes sure your video stream runs smoothly—even over slow networks—to another Saygus handset. **Saygus VPPhone** Price not set; saygus.com

RENOVATING

Step One: Fix everything

BY ADAM M. BRIGHT

ILLUSTRATIONS BY PAUL WOOTTON

Chicago road crews are scrambling to fill 67,000 potholes a month. Communities in Pennsylvania rely on 100-year-old water pipes made of wood. Squirrels still cause widespread blackouts. The country's 600,000 bridges, four million miles of roads, and 30,000 wastewater plants desperately need attention. The solution isn't patches, it's an overhaul. Soon roads and power lines will fix themselves, and we'll mine energy from sewage. America's 21st-century tune-up won't happen overnight, but we could start reaping the benefits (faster broadband! cleaner water!) within the next few years.

MESS #1: TRANSPORTATION

Defeating soul-deadening gridlock, monster potholes and dangerous road ice

CARS THAT REPORT POTHOLES

TASK: Fix the third of major roads that are in poor shape

STATUS: Three years to a prototype

In a new system developed at Northeastern University, vehicles that cover lots of asphalt—taxis, buses, garbage trucks—will be outfitted with acoustic wave sensors to detect potholes before the human eye can see them. Sound waves probe the top three feet of the road for telltale air pockets and small cracks, while ground-penetrating radar looks inside bridge decks for corrosion and lasers scan the road surface. A cellular data connection sends data to control centers, where it can be assembled into maps of trouble spots.

BRIDGES THAT FLEX ON THE FLY

TASK: Upgrade the 26 percent of decrepit bridges

STATUS: Pedestrian versions exist; traffic bridges in 10 years

Regular bridges are fairly rigid structures that break down over time from stress. "Tensegrity" structures disperse load over a nest of tensed cables and compressed struts that allow them to be both flexible and structurally rigid. Now the University of California at San Diego is developing traffic-bearing tensegrity bridges with feedback sensors to guide subtle adjustments in cable length, which could alleviate the shifting stresses of an overlaid truck, counteract the vibration frequency of an earthquake, or disperse the load of a severed cable.

ROADS THAT DE-ICE THEMSELVES

TASK: Reduce the 1,300 road deaths a year from snowy and icy winter conditions

STATUS: In testing by more than 20 state departments of transportation

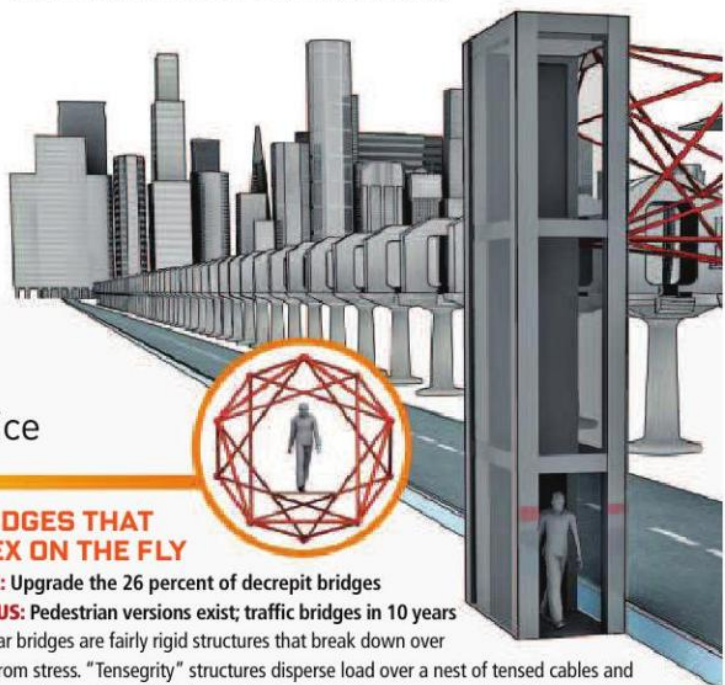
A new road coating called SafeLane not only gives tires more traction, it actually helps prevent the accumulation of ice and snow by holding on to de-icing salts, allowing road crews to scatter salt a couple of days before a blizzard rather than waiting until the snow is already on the ground. SafeLane consists of layers of epoxy mixed with dolomitic limestone. The epoxy layer is snowplow-proof, lasts up to 15 years, and helps seal the pavement to keep corrosive salts from leaching down to steel bars in sensitive bridge decks. Anecdotal results from its first five years in the field show up to a 70 percent decrease in winter accidents.

CONCRETE THAT SENSES CRACKS AND HEALS ON ITS OWN

TASK: Replace miles of concrete highways with smarter versions

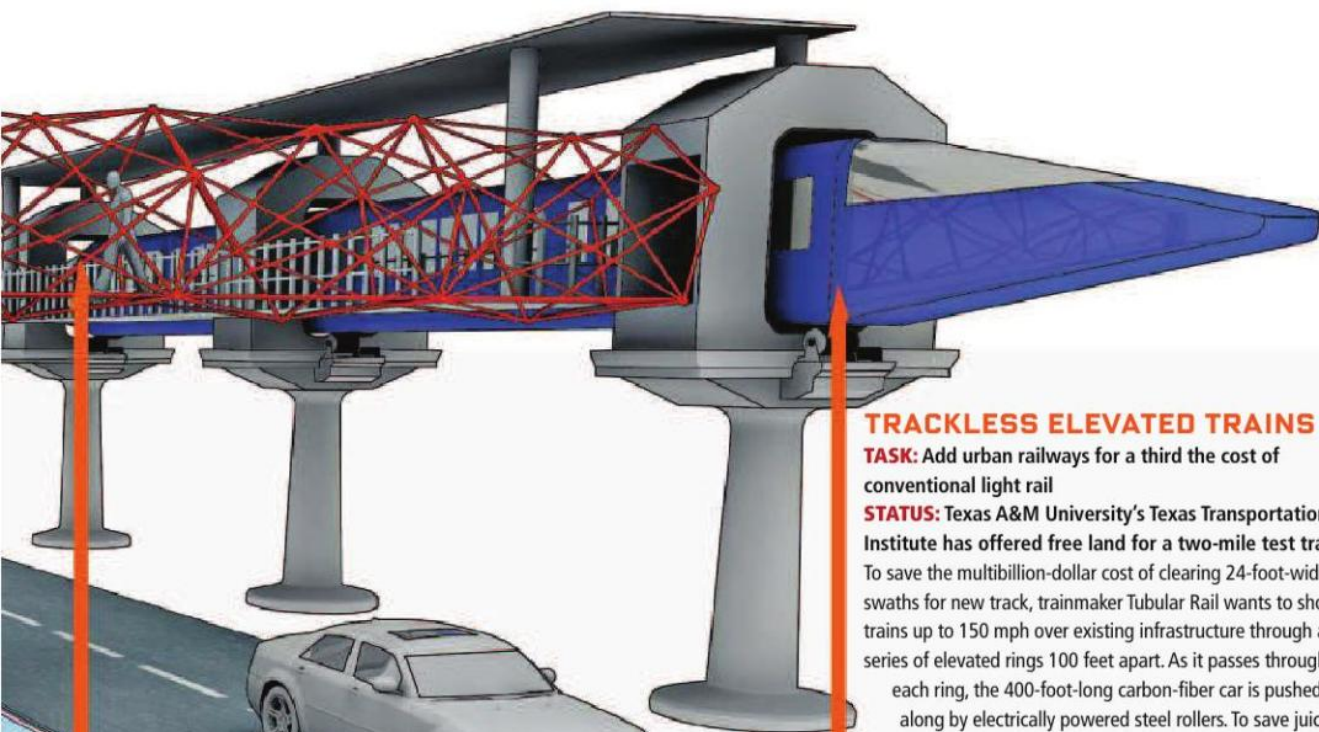
STATUS: Field-testing for self-sensing concrete in progress

Carbon nanotubes are prized for both their strength and their piezoresistance—they change their electrical resistance as they're stressed. Xun Yu, a mechanical-engineering professor at the University of Minnesota–Duluth, is cooking up a concrete mix that contains 0.1 percent carbon nanotubes, making it harder to crack than traditional concrete, and smart too. By embedding electrodes into it as it sets, Yu can measure changes in electrical resistance to detect compression from passing cars. Future versions will better calculate speed and vehicle weight on the go for a real-time view of the road's stress. Meanwhile, a new concrete mix developed by Victor Li, a professor of civil and environmental engineering at the University of Michigan, contains unhydrated cement grains that are activated when exposed to carbon dioxide in air and water from rain—exactly what you'd find in a small crack in the road. The reaction produces a calcium carbonate seal, restoring the slab to its normal load-bearing capacity.



AMERICA

THE FUTURE OF
ENGINEERING



TRACKLESS ELEVATED TRAINS

TASK: Add urban railways for a third the cost of conventional light rail

STATUS: Texas A&M University's Texas Transportation Institute has offered free land for a two-mile test track

To save the multibillion-dollar cost of clearing 24-foot-wide swaths for new track, trainmaker Tubular Rail wants to shoot trains up to 150 mph over existing infrastructure through a series of elevated rings 100 feet apart. As it passes through each ring, the 400-foot-long carbon-fiber car is pushed along by electrically powered steel rollers. To save juice, the motors gear up only as a train approaches; up to 90 percent of the kinetic energy of the train can be recaptured as the rollers wind down.

GLOWING CEMENT

TASK: Use phosphorescent highways to reduce the 50 percent of fatal highway accidents that happen at night

STATUS: Prototypes have been demonstrated
Nanophosphors are just what they sound like: tiny particles that glow after exposure to the sun. Scientists at the Council for Scientific and Industrial Research in South Africa have been adding them to materials such as cement and paint to create things like self-illuminating lane markings and roads that shine without overhead streetlights. Both could help reduce late-night lane drifting, as well as collisions with animals (and pedestrians) on unlit rural roads. Currently the glow lasts just a few hours, but researchers are experimenting with additives to find a more potent blend that will shine all night long.

HIGHWAYS THAT STORE HEAT

TASK: Embed roads with water-carrying pipes that hold onto the sun's energy

STATUS: Projects already in place in Europe

Road Energy Systems, designed by the Dutch engineering firm Ooms Avenhorn, captures energy from hot or cold asphalt. A grid of water circulated just beneath a special blacktop is heated in summer or cooled in winter before being pumped down to naturally insulated aquifers 300 feet belowground. The hot or cold water can then be used by nearby buildings. In summer, the stored cold water also helps cool the road to keep it from softening and deteriorating. In winter, the hot water keeps ice from forming.

WATER

Replacing treatment plants that use too much power, and 19th-century networks of leaky pipes

Our water infrastructure is older than our roads and power grid, with many pipes sitting in trenches dug by hand in the 1800s. In parts of the Northeast, up to 50 percent of our clean water leaks into the ground between the treatment center and the tap. Across the country, we lose an average of seven billion gallons of drinking water a day to leaks—and we have an 800,000-mile network of pipes that needs constant monitoring and repair. We also use far too much energy treating all our water, regardless of its end use, and piping it long distances. Besides fixing up the nation's pipes, the future of water is cleaning only what we need.

A NEIGHBORHOOD-SIZED SALTWATER PURIFIER

TASK: Decentralize our clean-water system

STATUS: Prototypes now; commercial units within a year
Yoram Cohen, a University of California at Los Angeles chemical engineer, has a solution for thirsty communities in states like California, which burns 20 percent of its power treating and pumping in water from far-off high-grade reservoirs: to spread out the task. His tanning-bed-size reverse-osmosis

machines could be deployed up and down the coast, with each unit tapping into the ocean to provide neighborhoods with about 5,000 gallons of drinking water per day. The units carry software that can fine-tune filtering in response to local changes in water temperature, salinity, pH and silt, and can be remotely controlled from a central operations center.

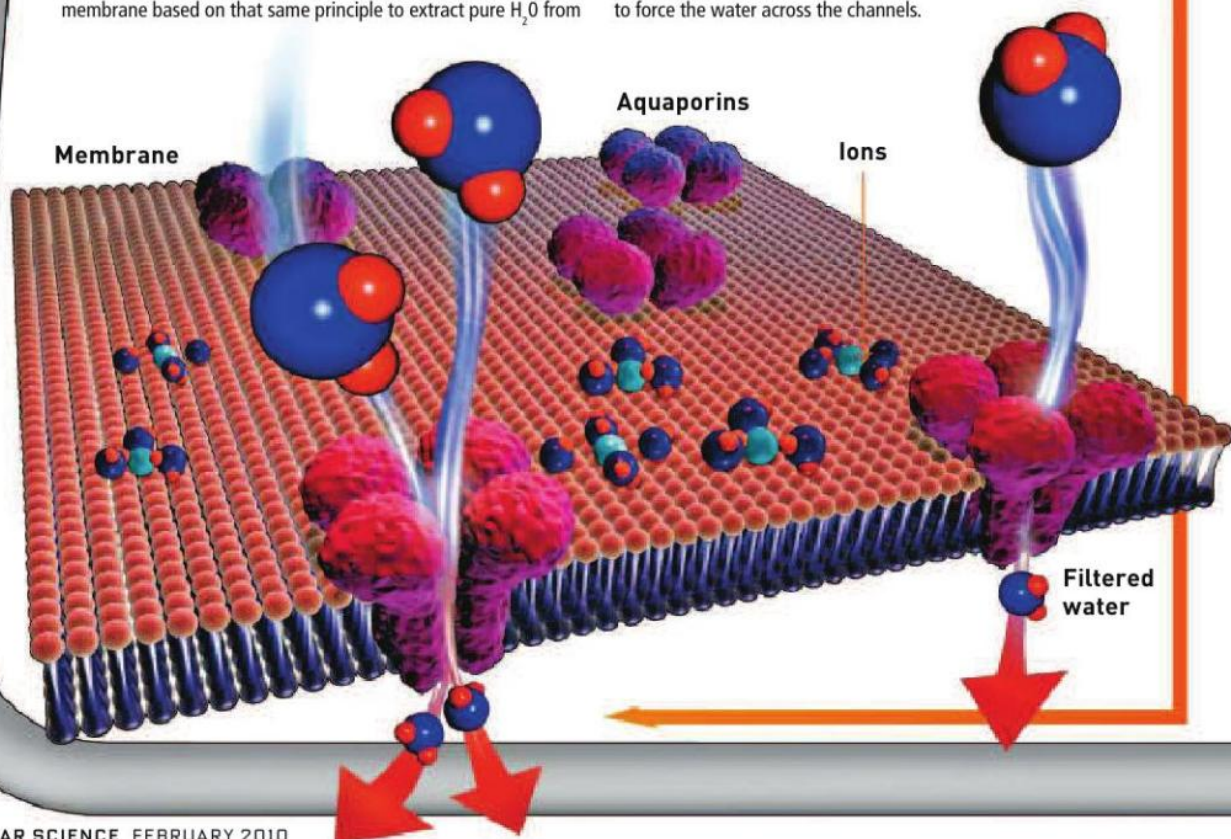
CLEAN WATER LIKE PLANTS DO

TASK: Treat our water on fewer terawatts

STATUS: First small-scale versions by 2011

Plants pull water into their roots by osmosis, using tiny channels called aquaporins, a method that doesn't require any energy. Now a Danish company called Aquaporin is developing a membrane based on that same principle to extract pure H_2O from

saltwater at about a third of the cost and a tenth the energy of conventional reverse-osmosis systems. The membrane's protein channels, each just a few nanometers across, allow a stream of water molecules—and only water molecules—to pass single file at a rate of one billion per second. No pumps are needed to force the water across the channels.



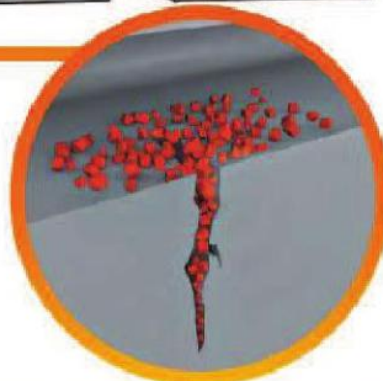


CLOT LEAKY WATER PIPES

TASK: Pump rubberlike blocks into our system to find and automatically fix leaks

STATUS: Deployed in the U.K. in 2008

Scottish oil-and-gas company Brinker Technology has a no-dig system of pipe repair that mimics the way clots form at a cut. When a leak is detected, a service truck could drive to a nearby fire hydrant and pump in Platelets—squishy, rubberlike cubes and balls ranging in size from less than a millimeter to nearly two inches across, depending on the size of the leak. The Platelets travel in the pipe until the outflowing pressure pulls them toward the crack. There, they bunch together to form a long-lasting clot. Utilities don't even need to know exactly where the leak is located.

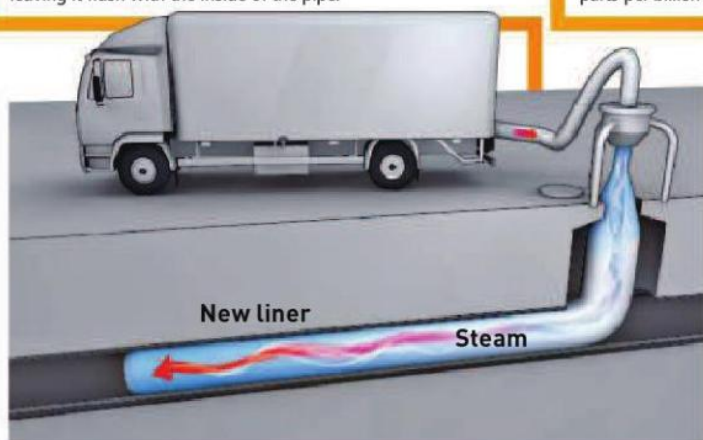


LAY NEW PIPES WITHOUT DIGGING TRENCHES

TASK: Deal with 240,000 annual water-main breaks more quickly by using simple slide-in liners

STATUS: Thousands of feet of pipe repaired since March

Another way of fixing broken pipe without summoning the backhoes is to coat it with a new inner lining—already common today in sewage pipes, which are under less pressure because they rely on gravity to move their contents along. But Missouri-based Insituform Technologies's new InsituMain liner can withstand the internal forces of pressurized pipe, allowing in-place repair of drinking-water mains. Instead of a full-length trench, two access points (up to 700 feet apart) are cut on either side of the broken pipe. Then workers insert at one end a flexible liner made from a felt-and-glass-fiber composite and soaked in thermosetting epoxy resin and pull it through the inner walls of the crumbling pipe. Exposing the liner to steam or hot water stiffens and seals it, leaving it flush with the inside of the pipe.

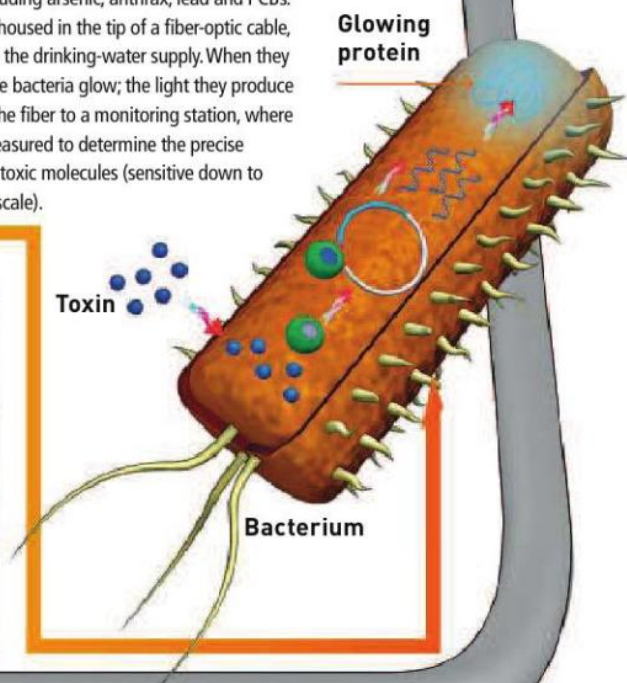


BACTERIA THAT MAKE TOXIC WATER GLOW

TASK: Install phosphorescent poison detectors at the nation's 155,000 drinking-water systems

STATUS: Commercially available in 2-5 years

Bacteria are little geniuses at identifying molecules. They're also prolific, cheap, and easy to manipulate, which makes them ideal workers. Using genetically modified, nonharmful strains of *E. coli*, chemist Sylvia Daunert of the University of Kentucky has designed a prototype biosensor system capable of detecting a variety of drinking-water toxins, including arsenic, anthrax, lead and PCBs. The bacteria are housed in the tip of a fiber-optic cable, which dangles in the drinking-water supply. When they detect a toxin, the bacteria glow; the light they produce is carried along the fiber to a monitoring station, where its intensity is measured to determine the precise concentration of toxic molecules (sensitive down to parts-per-billion scale).





MESS #3:

POWER

Overhauling inefficient plants and an ancient grid

A 2006 study at Lawrence Berkeley National Laboratory found that power interruptions cost the economy about \$79 billion annually, or about one third of national electric spending, thanks to our aging grid. Meanwhile, energy use

is expected to grow by 1,150 terawatt-hours—the equivalent of adding 13 New York Cities—by 2030. A smarter power grid will surely help, but we'll need additional innovations like these to keep up with spiking demand.

Superconducting tape

Liquid N₂



HANG SUPERCONDUCTING CABLES THAT WON'T LEAK ELECTRICITY

TASK: Replace miles of copper wire with cables that carry up to 10 times as much electricity per cubic inch

STATUS: 10–20 years to wide use
Instead of clearing paths for thousands of miles of new power lines to carry renewable energy across the country, we could restring the existing ones to run with high-temperature superconducting cables like those being studied at Oak Ridge National Laboratory. The cables transmit electricity along a one-micrometer-thick superconductive layer of tape wrapped around a stainless-steel tube full of liquid nitrogen that cools the line down below -321°F . In that chilled superconducting state, the lines lose no energy to resistance (today's copper cables lose 5 to 7 percent).

CRAM MORE COPPER UNDERGROUND

TASK: Replace thousands of miles of buried wire with a better-insulated version that carries 25 percent more power

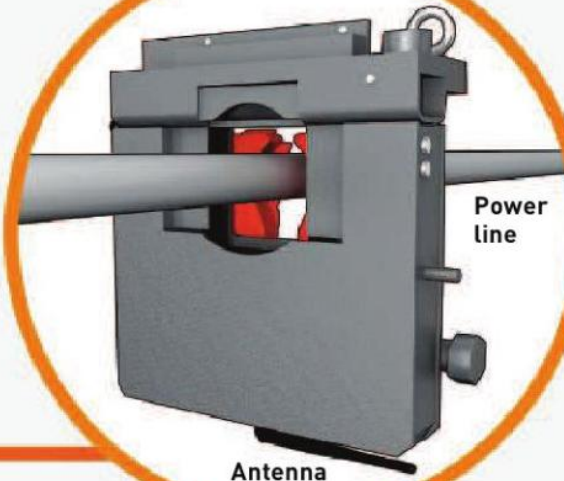
STATUS: 5–10 years away from widespread use
In urban areas, overhead power lines are a nuisance and a danger, which means most electricity crosses the city in underground tubes. As urban power demands increase, we could rip up streets to lay new lines, but an easier solution is just to cram more copper into the conduits we already have. That's what the Electric Power Research Institute (EPRI), an industry R&D consortium, is aiming for with a new insulation material that's embedded with vinylsilane-coated particles of silicon dioxide to give it 33 percent more insulating ability than existing line coatings. That means the next generation of power lines could carry up to a quarter more current without adding any more bulky insulation.

COPPER-CRAWLING ROBOTS

TASK: Deploy fleets of nimble robots that scoot along power lines, looking for flaws so that humans don't have to

STATUS: First commercial versions around 2012

Conventional inspection is slow and expensive, often requiring a helicopter flyby. EPRI is working on a robot that can autonomously survey an 80-mile length of line twice a year for cheaper and more reliable inspections. The robot will straddle the line, carrying a camera, a diffused scanning laser and on-board image-analysis software, which it will use to construct both a visual history of the deterioration of the line, as well as a 3-D map of encroaching tree branches and other potential problems.





UNDERGROUND POWER LINES THAT HEAL THEMSELVES

TASK: Coat cables with a self-repairing salve

STATUS: Commercially available in 10–15 years

Another way to dig up fewer streets is to avoid unearthing cables for small repairs. Whenever there's a nick or hairline crack in an insulation sheath, the electrical field in the underlying copper subtly shifts. In a new insulation being developed by EPRI, nanoparticles sensitive to this shift heat up and melt surrounding polymer molecules, forming a fresh protective scar. As today's decrepit lines gradually go kaput (about a quarter are already past their intended lifetime), EPRI hopes to replace them with these self-mending ones.

MAKE ENERGY LIKE PLANTS DO

TASK: Convert sunlight into chemical energy

STATUS: Last year, scientists found a plentiful raw material that can free oxygen from water

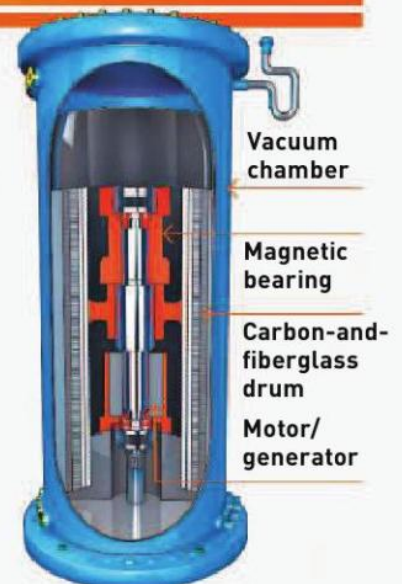
Solar panels are not the only energy-harvesting strategy under the sun. For years, scientists have also been trying to do what plants do—use sunlight to photosynthesize fuel. Until now, most approaches relied on impractically scarce materials like iridium as a catalyst that triggers the reaction. But last year, researchers at Lawrence Berkeley National Laboratory figured out how to use cobalt oxide, one of the most abundant industrial catalysts. To overcome the relative inefficiency with which cobalt oxide uses sunlight to crack water molecules and free the oxygen, researchers layered the catalyst on a tightly stacked scaffold that makes it effectively 1,600 times as efficient. The net result: Arrays of cobalt-oxide panels could provide a steady supply of oxygen, protons and electrons. The next goal is to find a similarly efficient second catalyst to transform the by-products into an energy-dense fuel like methanol to give gasoline a run for its money.

ADD STORAGE TO THE GRID

TASK: Build plants full of spinning drums that store electricity, so we can finally save surplus energy

STATUS: 20-megawatt plant under construction in Stephentown, N.Y.

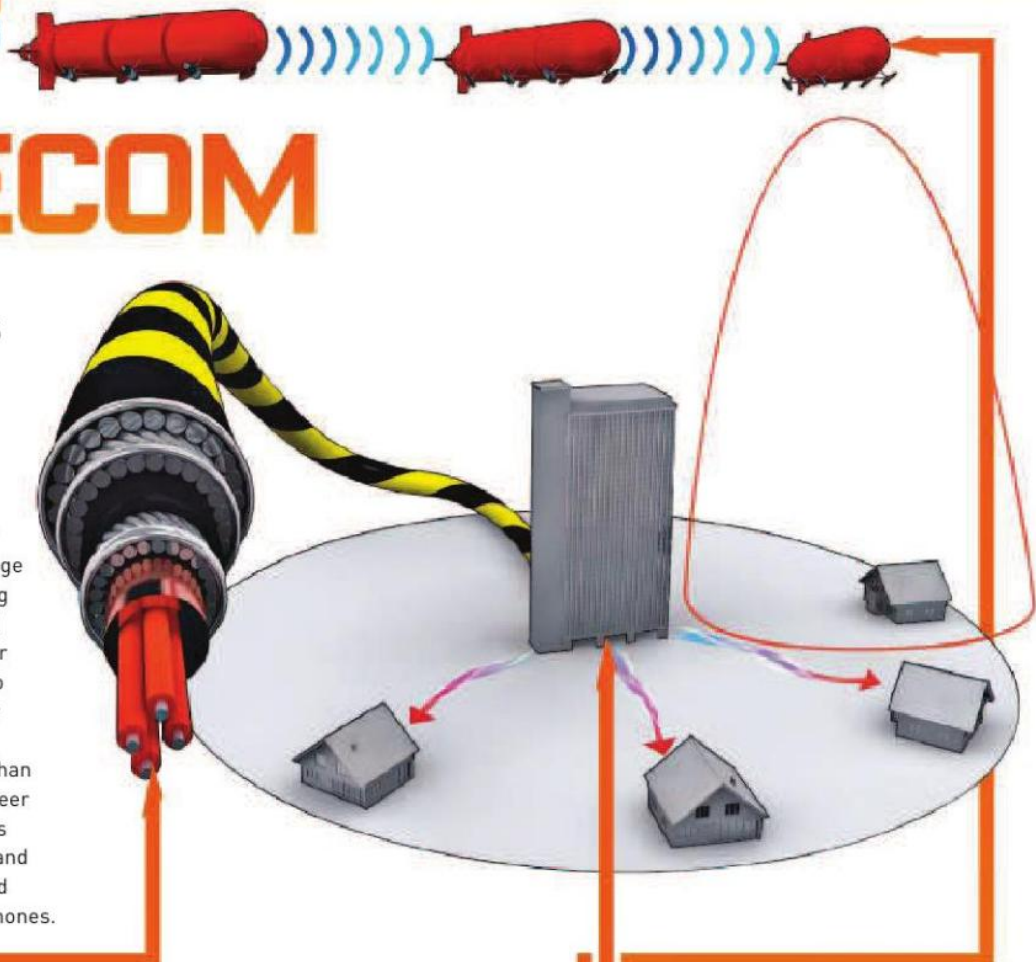
Incredibly, today's grid has practically no storage capacity. The electricity coming out of your socket was generated less than a millisecond ago, so power plants have to continually generate enough energy for the biggest spikes. To prepare for the power fluctuations endemic to renewable energy, we'll need to inventory excess power to use during cloudy, windless afternoons and nights. The Massachusetts-based company Beacon Power's solution is to store the grid's surplus energy in hundreds of spinning carbon-fiber-and-fiberglass drums. Each of its Generation 4 flywheels features a 2,500-pound rotor mounted on magnetic bearings and sealed in a vacuum to create a near-friction-free environment. Energy coming in from the grid accelerates the three-foot rotor to 16,000 rpm (about Mach 2), where it keeps spinning with at least 97 percent efficiency. To pump energy back into the grid, some of the rotational energy is bled off to power a generator on the main shaft. Each flywheel can store a 15-minute, 100-kilowatt charge and can discharge 150,000 times over 20 years.



TELECOM

Boosting anemic broadband speeds and wireless networks stuck in the 20th century

The U.S. ranks 17th worldwide in broadband access, but not for long—last year's stimulus package allotted \$7.2 billion for upgrading our underperforming broadband infrastructure. Our legacy copper wiring just can't carry the data to support HD-video streaming, for instance, and next-gen wireless networks are slower to roll out than in, say, Japan, because of the sheer size of this country. But advances in fiber-optic cables and broadband blimps could bring serious speed increases to homes and smartphones.



FASTER FIBER

TASK: Replace our international fiber-optic trunk lines with thicker cables that carry 10 times the data per second

STATUS: Demonstrated last year

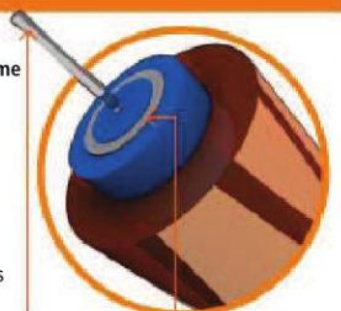
Our next generation of transoceanic submarine fiber cables may be built according to the Alcatel-Lucent design that recently set transmission speed records by moving data 10 times as fast as current cables. The new cables started with a fiber core that is on average 40 percent thicker than the ones currently draped across the ocean floor. Engineers designed an array of 155 lasers that emit light of different wavelengths, and in addition to encoding information in the timing of the light pulses the way current cables do, they modulated the polarization and the phase to pack extra data onto each light wave. The new fiber cables can send 15.5 terabytes—the equivalent of 400 DVDs—each second from Boston to Bilbao.

FLEXIBLE FIBER

TASK: Snake high-speed fiber-optics into virtually every home

STATUS: Available now

Corning's new, flexible ClearCurve cable features a nanomaterial mesh wrapped around the cable core that keeps the photons in line even when stapled, bent, or twisted around a nail—usually any such quick turns would make the line go dark. That means telecoms can finally put fiber-optic lines into people's homes, where cables often run up against right angles and tight squeezes from the sidewalk to the house. Verizon is already using the cable for its FiOS service.



Fiber core Nanomaterial

MAKE THE NETWORK AIRBORNE

TASK: Float broadband blimps above areas that are a headache to hardwire

STATUS: Delivery of a first ship to a military contractor this year; full platforms in 3–5 years

We're going to need to dig a lot more fiber and copper in the coming years to meet the exploding communications demand. Or we can just float a few blimps. Sanswire, a manufacturer of unmanned aerial vehicles, is working on a 525-foot helium- and fuel-gas-filled airship, the Stratellite, which would provide blanket broadband coverage from the tranquil heights of the stratosphere. Hovering at 65,000 feet, each blimp could provide phone, TV and high-speed Internet to an area about the size of Texas, without the lag times that have plagued satellite-based communications. Stratellites can even daisy-chain to link cities and rural areas across the country—all without a single new wire touching the ground. ▶

MESS #5:

SEWAGE

Banishing energy-hogging treatment plants and rotting pipes

Every year, Americans produce 12 trillion gallons of wet sewage and burn 21 billion kilowatt-hours of electricity to clean it to drinking-water standards. Why not put the smelly stuff to good use? Thanks

to clever new technology, sewage will be reclaimed to provide power, produce fertilizer and, eventually, yield clean water. In other words, sooner than you think, you'll be drinking your own urine.

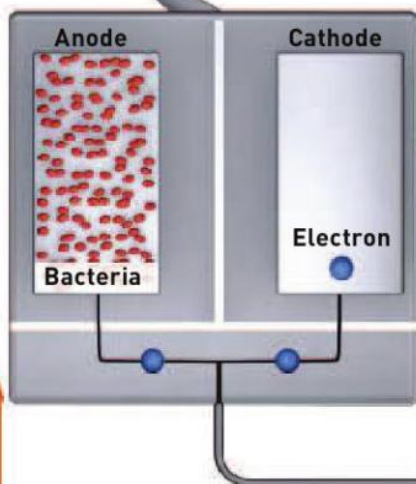


DROP ROBOTS DOWN THE DRAIN

TASK: Deploy fleets of autonomous machines to spot leaks in sewage pipes

STATUS: New models that use a laser to measure inside pipes could be ready by 2011

RedZone Robotics's new Solo sewer robots will use image-interpreting software developed at Carnegie Mellon University to analyze their video feeds and tag potential problems in the pipe, so a 10-hour run can be condensed to a two-hour highlight reel of dripping cracks and grasping roots. Each Solo carries a camera at either end, sonar to scan below the water, and lasers to search sewer walls for acid corrosion.

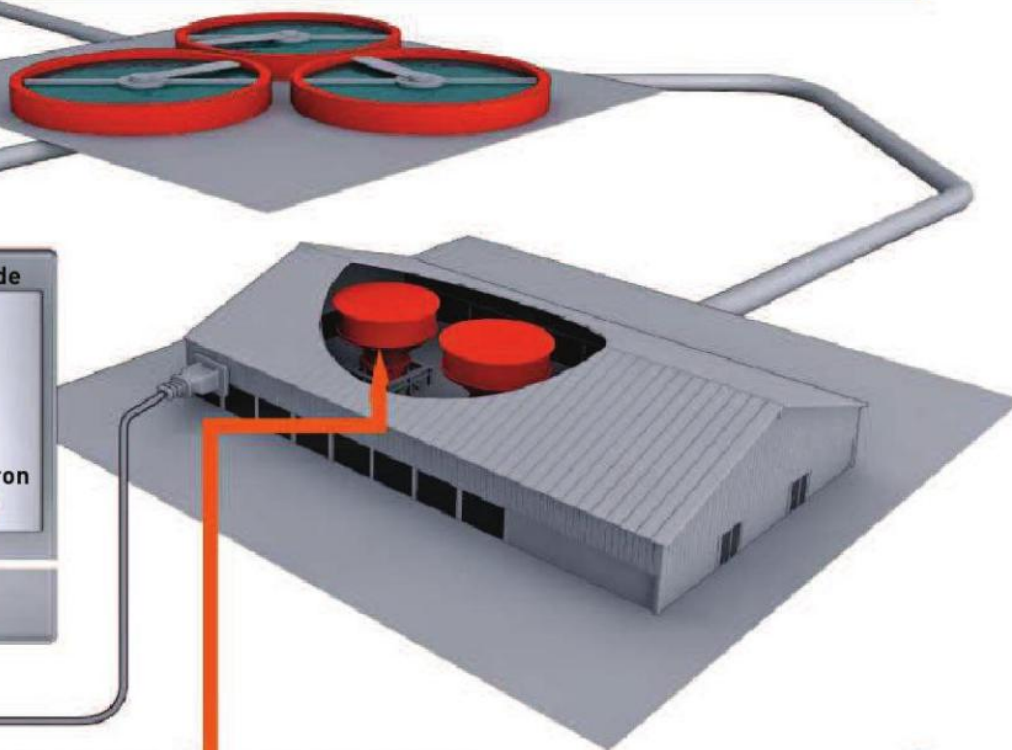


TURN SLUDGE INTO ELECTRICITY

TASK: Reduce the energy we use to treat wastewater, currently 1.5 percent of our total national power

STATUS: Field-testing reactors; commercial units by 2015

Bruce Logan, a professor of environmental engineering at Penn State University, has designed a microbial fuel cell to turn the chemical energy in sewage directly into electricity—and clean the sewage in the process. Bacteria housed on a graphite fiber anode break down the fats, proteins and sugars in sewage, freeing up a steady stream of electrons, which the bacteria transfer directly into the electrode. Those electrons move to the cathode, providing electrical power and, at the cathode, producing hydrogen gas.



RECYCLE URINE

TASK: Recover phosphorus and nitrogen from wastewater to make fertilizer

STATUS: First U.S. plant opened last June; another coming this year

Believe it or not, the wastewater of 100,000 people could yield an annual crop of about 200 tons of high-grade fertilizer. The Vancouver company Ostara hopes to use this fact to overcome our shrinking supply of recoverable phosphorus rock, one of three essential components of modern fertilizer. Ostara's PEARL Nutrient Recycling system extracts phosphates and other minerals like ammonia from municipal wastewater and then churns the nutrients into safe, slow-release fertilizer pellets sold under the name Crystal Green. The challenge is sequestering the urine, which accounts for just 1 percent of sewage by volume. One solution: source-separated toilets (think: a little bowl within a big bowl), already being tried in Sweden and Denmark.



IN LIVING COLOR
Mary Lou Jepsen
has invented a
hybrid computer
screen that blends
the best aspects
of both laptop and
e-reader displays.

SCREEN QUEEN

Mary Lou Jepsen has created massive holograms and cheap laptops for the developing world. Now she's rethinking the LCD screen, leading the way to the next great gadget: an e-reader to replace your laptop

BY LAUREN AARONSON
PHOTOGRAPHS BY JOHN B. CARNETT
DIGITAL IMAGING BY ERIC HEINTZ

For Mary Lou Jepsen, getting an MRI is not unlike getting a massage—a relaxing ritual, a rare slice of time when no work can possibly be done. I'm accompanying Jepsen to her doctor's appointment at Massachusetts General Hospital because it's the only few hours she can fit me in. She's in Boston for three days, in between trips to her Sausalito, California, houseboat and her apartment in Taipei, Taiwan, and she's booked back-to-back with appointments. Yesterday she had a meeting with the team at One Laptop Per Child, the nonprofit she helped create and with which she still collaborates on new computer designs. Today she's talking with her doctor about the medicine she needs to take to stay alive, after a tumor nearly killed her 10 years ago. Tomorrow she will appear at the Boston Book Festival in a debate about the future of reading, along with top executives from Sony and Google.

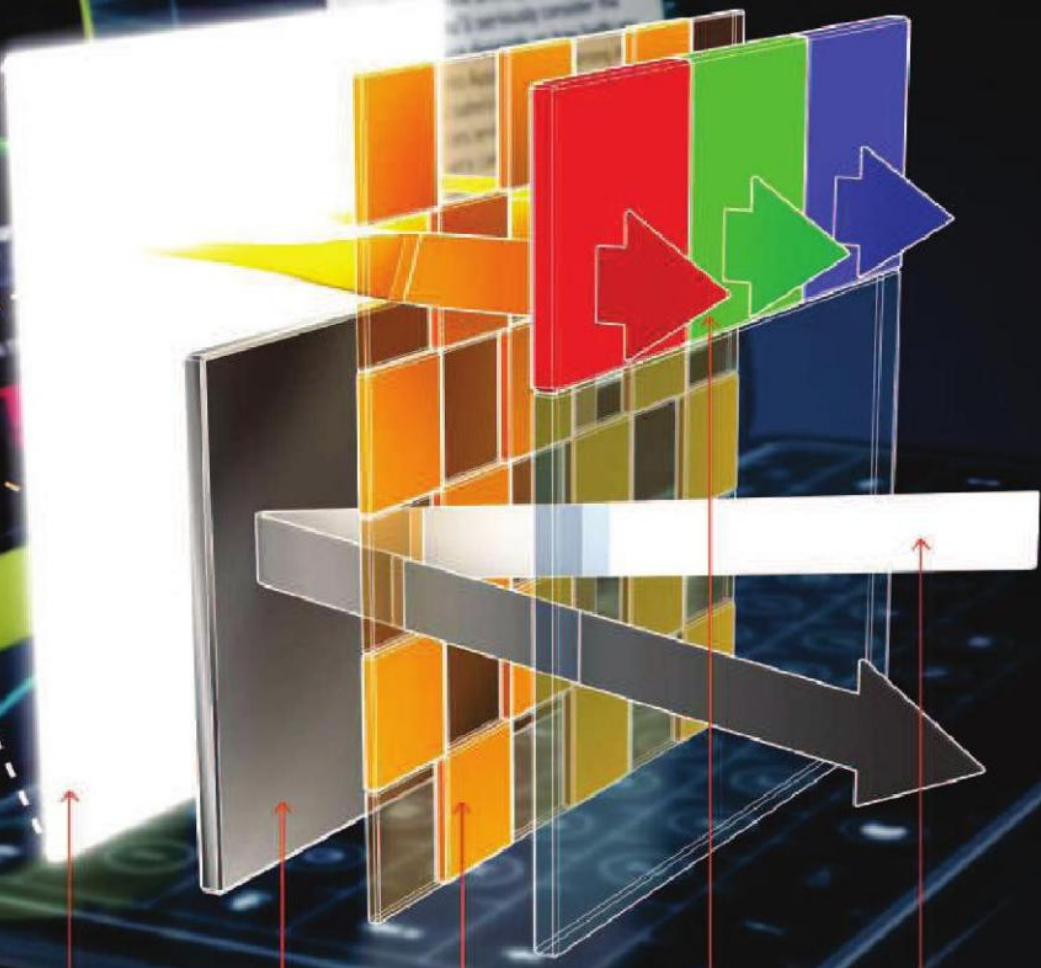
While Jepsen gets her brain scanned, I sit in the waiting room and guard the tote bag that contains the reason her life is so frenzied: a 10-inch slab of glass that, she says, merges the best of computers and e-readers into a single screen. Turn on the store-bought tablet PC that Jepsen's prototype screen sits in—she removed the old screen with a screwdriver and swapped hers in—and it looks and acts like any LCD screen, because it *is* an LCD, only better. LCDs display color and video, but they kill battery life. Electronic ink is more energy-efficient and paper-like, but it's black and white and is frustratingly slow to load a

new page. Jepsen's screen combines the best of both technologies. Flick a switch, and the bulb that makes the screen glow will dim. But instead of going dark, only the colors will fade. That's because in Jepsen's screen, ambient light can substitute for backlight, bouncing off the mirror-like material that Jepsen has added to each pixel to reflect shades of black and white. With the lamp completely off, the screen, called 3Qi (pronounced "three chee," as in *qi*, the Chinese word for "spirit," and a geeky pun on the 3G wireless network), displays letters as crisp and readable as those on Amazon's Kindle. In this mode, 3Qi uses about one fifth the power of a normal computer screen, Jepsen says. And unlike the E Ink-based Kindle or any other widely available e-reader, it still does everything a regular LCD does, including play videos.

As Jepsen will say in her talk tomorrow, "The future of reading is screens." She puts it to me more bluntly: "Books are toast." She's not talking about reading, just dead-tree delivery, and there's evidence to back her up. Between January and September of last year, \$112.5 million worth of digital, downloadable books were sold, up from \$7.2 million during the same period five years earlier. Since the introduction of the Sony Reader Digital Book in 2006 and the Kindle in 2007, the number of e-readers sold in the U.S. has more than doubled every year—an estimated one million in 2008, three million in 2009, and a projected six million this year. According to one forecast, that number could rise to 77 million worldwide by 2018.

That may be hard to believe given the single-task capability of current e-readers. But once a screen arrives that com-

SHINE A LITTLE LIGHT A schematic representation of a single pixel in Jepsen's hybrid LCD screen



A Backlight **E** Mirror **B** Layer of liquid crystals **C** Color filters **D** Ambient light

HOW IT WORKS

3Qi combines two kinds of displays—an ordinary color LCD and a low-power, high-resolution black-and-white version—into one package. Here's how it pulls it off

CREATING COLOR

Part of each pixel acts like one in a normal LCD screen: A backlight **[A]** shines through a layer of liquid crystals **[B]**. The crystals control how much light gets through, depending on how they shift their orientation when zapped with electricity. The light that makes it past the crystals passes through red, green and blue filters

[C], which tint and combine the light to create the colors on your screen.

BOUNCING BLACK AND WHITE

Turn the energy-sucking backlight down, and the pixel reflects light instead of producing it. Ambient light **[D]**, whether from a lamp or the sun, enters the display and hits a large part of the pixel that's covered

in a mirror **[E]**. The beams bounce back out through the liquid crystals, which change the brightness of the light that escapes, just like in the color mode. But instead of shuttling through color filters, which absorb and dim rays, that light exits through an empty space—so you see it as white, black or one of 254 shades of gray in between.



LENGTHY READING
Dropped into an existing netbook, the 3Qi screen adds about an hour of battery life. Devices designed to work specifically with the screen could extend that to nearly a day, Jepsen says.

PHOTOGRAPHS TAKEN AT CRIMSON CORNER, CAMBRIDGE, MASS.

SPECIAL REPORT

HOW TO SAVE THE OCEANS

A Plan for Rescuing the Other 71 Percent of the Planet **P.46** **PLUS:** 12 Experts Explain What They Would Do **P.56**

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P.70

**PLUS:
VACATIONS
FOR YOUR
BRAIN**

P.72

AND: Blimps Are Back! **P.34**

A Jet-Propelled Surfboard **P.17**

Self-Sharpening Teeth **P.36** **A Blind Man Drives Daytona** **P.44**



SOLÉ POWER TILE

ROOFING TILES THAT DOUBLE AS SOLAR PANELS

Billed as the first curved photovoltaic roofing product, the Solé Power Tile replaces add-on solar panels with a new flexible solar laminate bonded to a polymer base that gives tiles the curved shape of regular terra-cotta. SRS partnered with US Tile, the country's largest clay-tile manufacturer, to make the switch seamless for homeowners: Have the navy tiles installed across the whole roof, or replace just a small section. Depending on how many you install, the tiles can cut your monthly utility bill in half. They can also produce 10 to 15 percent more energy than comparable solar panels, by virtue of a thin-film technology that deflects heat and converts lower levels of light—such as during dawn, dusk or very cloudy days—into electricity. **\$50/square foot (installed); ustile.com, srseenergy.com**

DAN SAELINGER

TALES OF TESTING: RYOBI DUET POWER PAINT SYSTEM

A PAINTER BUILT FOR TWO

To make painting my hallway as quick and painless as possible, I turned to the first powered paint dispenser strong enough to let two people paint at the same time. No fighting over who gets the robotic assist—I used the power roller while my friend handled the tight spaces with the cut-in and corner pads. Dual-control knobs differentiate the flow to each brush and conserve paint. Meanwhile, a pump compresses tubes to keep the paint moving, giving it an even consistency and my walls a smooth finish. Afterward, I pumped the leftover paint back into the can with the flip of a switch and ran warm water through the system to clean it. Next project!—NICOLE DYER **\$130; ryobitools.com**



HEADLINES THE ANNOTATED MACHINE

AIRSHIPS RISE (AGAIN)

The next generation of dirigibles takes flight

A whirring comes across the sky. From 20,000 feet above the Mexican border or Afghanistan's Korengal Valley, a vehicle as long as the Chrysler building is tall drifts into the stratosphere. It looms like a cloud and stays put for 21 days, scanning for body heat below. These blimps are lighter than air, fuel-efficient and quiet—which is why they could become the military's go-to vehicles for surveillance and transport.

—BARRY HARBAUGH

SKY HQ

Last summer, the U.S. military awarded Northrop Grumman a \$517-million contract for a Long Endurance Multi-Intelligence Vehicle (LEMV). The 300-foot-long aircraft gets about 40 percent of its lift from its hull's aerodynamic shape. It can stay aloft for three weeks at a time running surveillance. Northrop says the LEMV will be ready for action by the beginning of next year.

Pop Proof

The pressure within the LEMV's **helium envelope** is low enough that if it is somehow shot or punctured, the ship will neither explode nor tumble from the sky.

Unmanned

The military plans to deploy the LEMV without anyone on board. Autonomous sky trains, made up of a series of ships tied together, are a possibility (although current flight regulations require a pilot to steer ships through commercial airspace).

Efficient

The ship's four diesel engines cost \$15,000 to fuel on a three-week mission—one tenth the consumption of a helicopter and one quarter that of an airplane used on similar missions.

Helium envelope

FISH OUT OF WATER

Unveiled in 2009 by the EMPA, the Swiss federal laboratories for materials science and technology, this balloon has electric actuators attached on either side of its body. When voltage is applied, polymers in this 26-foot-long helium-filled balloon's skin expand and constrict like a fish, propelling the craft silently. Christa Jordi, the lead scientist on the project, says the trout balloon could be used in such sound-sensitive situations as spy missions, animal observation and stadium events. The Flaming Lips need one. . . .

Shock Propulsion

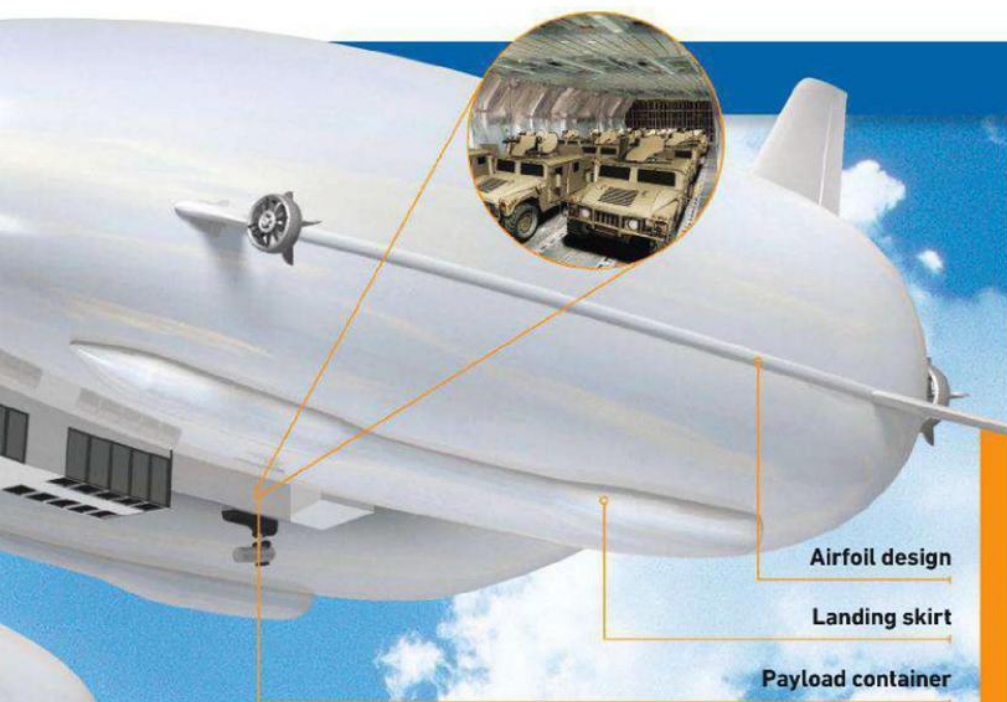
Dielectric elastomer actuators act as artificial muscles, compressing and expanding when charged with electricity.

Bone Structure

A thin and rigid **carbon-fiber-reinforced epoxy skeleton** runs lengthwise through the "fish" and, like a spine, bends without any hinged joints.

Clear Skin

The helium-tight membrane is made of **Heptax**, a plastic that's also used to seal food products.



HEAVY LIFTER

Hybrid Air Vehicles, which teamed with Northrop on its design for the LEMV, is working on a set of three larger-capacity hybrid airships that can carry up to 200 tons and will be the biggest airborne carriers in the world, the smallest of which is larger than a 747. The HAV 606 (shown here), is 607 feet long and has a helium envelope of 16 million cubic feet, twice the size of the *Hindenburg*. Hybrid Air plans to sell the ships, which take 24 months to build, for mining and oil exploration.

Well-Balanced

When fully loaded, the HAV is no longer lighter than air (the weight of the load is greater than helium's

lift) and its **airfoil design**, wide and aerodynamic, becomes crucial for staying aloft.

Dock Anywhere

Landing skirts, which allow the craft to touch down, are retractable and amphibious, so the LEMV can land on ground or water. The crew activates a vacuum anchor when the craft lands, which does away with the need for a mooring tower.

Roomy Interior

A **payload container** can carry the weight of up to 85 humvees.

(CONTINUED FROM PAGE 331)

less than a mile deep, though, they must bury armored cable to protect it from ship anchors, fishing trawls, dredging gear, and attacks from sharks, which are drawn to the line's electricity.

For all the money Hibernia and its clients will make from a 60-millisecond trip across the Atlantic, the installation will be slow. Crews on two ships, the *Sovereign* and the *Cable Innovator*, will deploy 24-ton ploughs to cut a trench up to six feet into the seabed, into which they will lay the cable. The top speed is about one mile an hour. Each ship is outfitted with a dynamic positioning system that keeps it in place while laying cable, regardless of currents or winds. If something gets in the way, such as another submarine cable, the

THE CABLE MUST BE PROTECTED FROM SHIP ANCHORS, FISHING TRAWLS AND SHARKS.

crews will use a remotely operated vehicle equipped with a pair of high-pressure water "swords" to break apart sediment. The ROV then uses a mechanical arm to bury the new cable underneath the obstacle and into the temporarily softened earth. "The seabed always throws up something unexpected," says Stuart Wilson, the manager of cable-route engineering for Global Marine Systems, the company installing the Hibernia line.

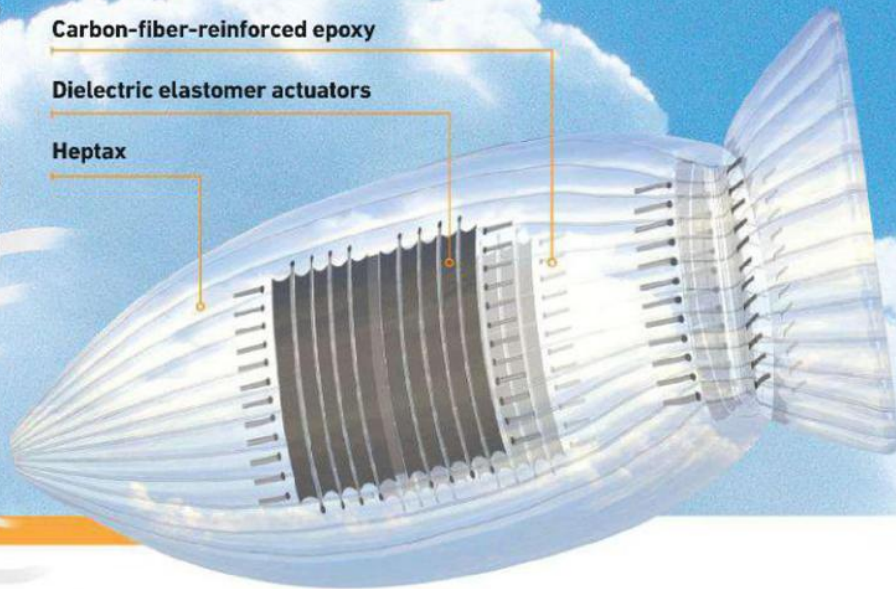
Hibernia says its cable will go live next year, connecting it to Hibernia's Global Financial Network, which has fiber optics running 15,000 miles between financial centers from Chicago to Frankfurt. But the New York-to-London line could be the company's biggest draw, providing a competitive advantage of just five milliseconds—about the amount of time it takes a bee to flap its wings.

—MATT DELLINGER

Carbon-fiber-reinforced epoxy

Dielectric elastomer actuators

Heptax



FASTER THAN A SPEEDING BULLET

China's supertrains set new speed records while the U.S. plays catch-up

BY KATHERINE BAGLEY ILLUSTRATION BY NICK KALOTERAKIS



Last December, a prototype passenger train traveling between Shanghai and Beijing reached 302 mph, breaking the speed record for unmodified commercial-use high-speed rail. The feat, a culmination of six years of development by CSR Sifang Locomotive & Rolling Stock, was an example of the revolution quietly transforming rail. In the past five decades, 26 countries have built, or have begun developing, high-speed-rail lines. These include France's TGV to the Seoul-to-Pusan line in South Korea. Even the U.S., which has lagged behind other nations, has acknowledged the need for high-speed rail to improve the nation's infrastructure, strengthen the economy, and enhance international competitiveness.

High-speed-rail travel generally falls into two categories:

▲ FAST FLIERS

Magnetically levitated trains traveling through a partial-vacuum tube could reach speeds of 621 mph.

conventional, which involves electricity-powered trains traveling on steel-wheel-on-steel-track systems, that generally operate at speeds of around 200 mph, and maglev, which commonly rely on magnetic repulsion between an onboard magnet and another embedded in its track, and operate at speeds of up to 270 mph. The vast majority of development has gone into conventional systems. In an effort to mitigate the growing congestion caused by its rapidly growing population, China's rail authority says it will add 9,941 miles of track by 2020, more than tripling the size of its current network.

In the U.S., innovation has been slow. Geographic factors

(cities are too far apart), financial limitations (it is expensive to build through cities) and politics have acted as obstacles. But plans are making headway. Vice President Joseph Biden announced in February that the U.S. would invest \$53 billion in high-speed rail over the next six years.

For all the progress in conventional high-speed rail, some of the most exciting research is being done on maglev systems. In 2004, citing concerns about high costs, Chinese officials scrapped plans to build a maglev line between Shanghai and

Planned High-Speed-Rail Projects in the U.S.

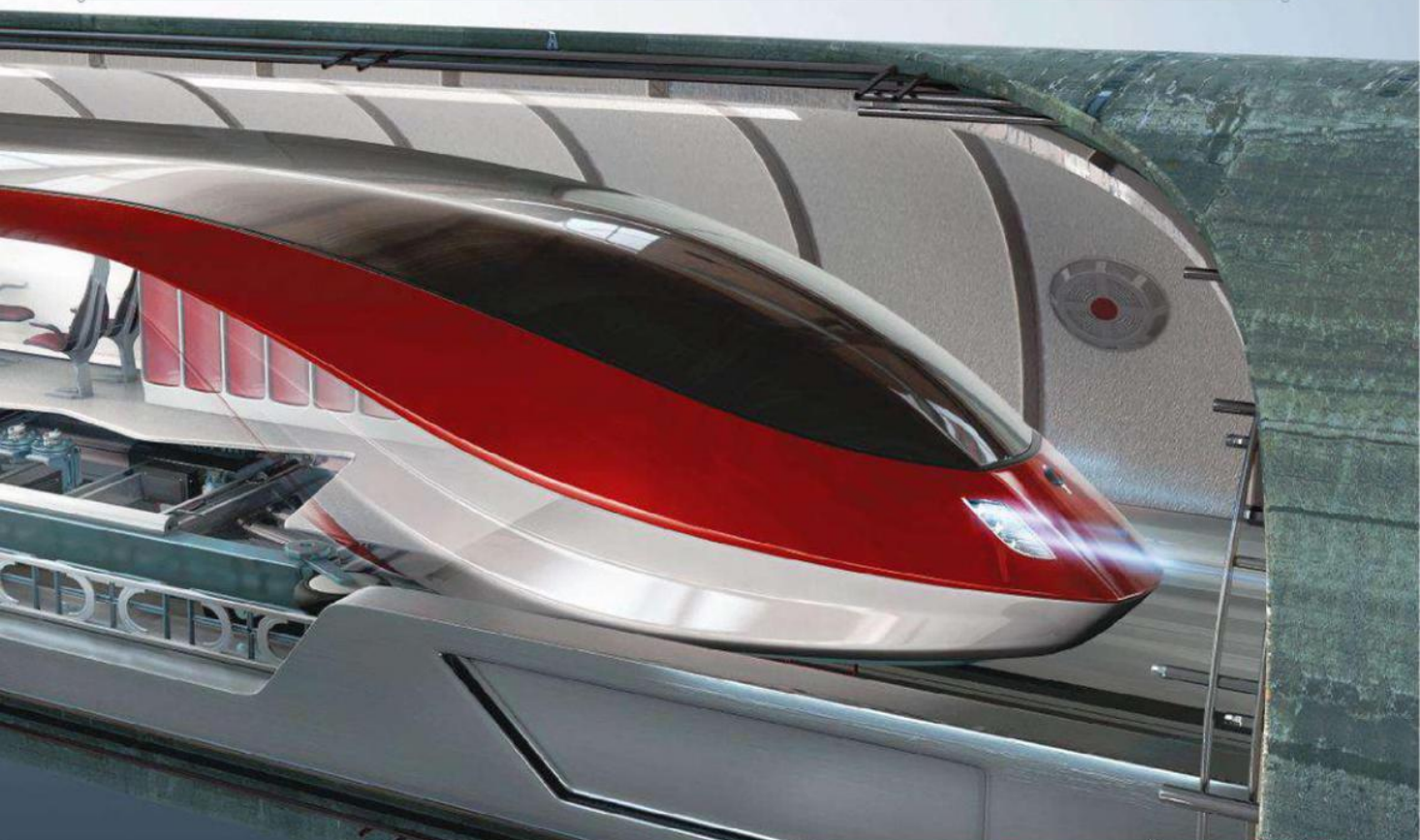
Major corridors	Funding*	Total miles	Top speed
California	\$3 billion	1,955 miles	220 mph
Northeast Corridor	\$683 million	727 miles	110 mph
Charlotte-Raleigh-Richmond-Washington, D.C.	\$688 million	480 miles	110 mph
Eugene-Portland-Seattle-Vancouver	\$637 million	467 miles	150 mph
Kansas City-St. Louis-Chicago	\$1.17 billion	570 miles	110 mph

Expected completion

2015
2020
2025
2030



TO AND FRO The trade group US High Speed Rail Association envisions a 17,000-mile network of track. The proposed 220mph trains could cut travel times in half.



Beijing, so for now, maglev trains cover only short distances. The fastest maglev train currently operating reaches 268 mph on the 7.5-minute, 19-mile trip between Shanghai's Pudong airport and the city center. Engineers at China's Southwest Jiaotong University, however, are at work on the next generation: evacuated-tube maglevs that could smash all previous speed records.

PAUL WOOTTON

Vactrains: How Fast Is Superfast?

In 1972, Robert Salter, a physicist with the RAND Corporation, posited a "very high speed" train that would travel along magnetic rails "much as a surfboard rides the ocean's waves." Unlike a surfer, though, this train would be sealed in a vacuum, and therefore would not only face no rolling resistance from the rails but also no wind resistance from the atmosphere. No one has yet built one, but last year engineers at Southwest Jiaotong University in China announced plans to build a 500-foot-long prototype for a 600mph vactrain system. And Daryl Oster, founder of the Florida-based company et3, says his proposed maglev could travel at up to 4,000 mph and could zip between New York and Los Angeles in 41 minutes.

*Numbers are estimates from the U.S. Department of Transportation Federal Railroad Administration

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140TH ANNIVERSARY ISSUE

THE NEW AGE OF FLIGHT

- ▶ **Super-Quiet Supersonic Jetliners** P. 40
- ▶ **The First Personal Electric Plane** P. 56
- ▶ **How to Survive a 23-Mile Free Fall** P. 54
- ▶ **Clip 'n' Fold Paper Airplanes!** P. 64

PLUS:
HELP US
SOLVE A
MYSTERY
140 YEARS
IN THE
MAKING P. 96

- ▶ **C.J. Chivers** **Makes the Case for Human Pilots over Drones** P. 58
- ▶ **James Fallows** **Reports on China's Green-Aviation Experiment** P. 46





Making Hybrids Huge

SUGAR VOLT, BOEING

TARGET
DATE
2035

The best way to conserve jet fuel is to turn off the gas engines. That's only possible with an alternative power source,

like the battery packs and electric motors in the Boeing SUGAR Volt's hybrid propulsion system. The 737-size, 3,500-nautical-mile-range plane would draw energy from both jet fuel and batteries during takeoff, but once at cruising altitude, pilots could switch to

all-electric mode [see "High Voltage," page 56]. At the same time Boeing engineers were rethinking propulsion, they also rethought wing design. "By making the wing thinner and the span greater, you can produce more lift with less drag," says Marty Bradley, Boeing's principal investigator on the project. The oversize wings would fold up so pilots could access standard boarding gates. Together, the high-lift wings, the hybrid powertrain and the efficient open-rotor engines would

make the SUGAR Volt 55 percent more efficient than the average airliner. The plane would emit 60 percent less carbon dioxide and 80 percent less nitrous oxide. Additionally, the extra boost the hybrid system provides at takeoff would enable pilots to use runways as short as 4,000 feet. (For most planes, landing requires less space than takeoff.) A 737 needs a minimum of 5,000 feet for takeoff, so the SUGAR Volt could bring cross-country flights to smaller airports. —ROSE PASTORE



Jet Setters

NASA asked the world's top aircraft engineers to solve the hardest problem in commercial aviation: how to fly cleaner, quieter and using less fuel. The prototypes they imagined may set a new standard for the next two decades of flight

ILLUSTRATIONS BY Nick Kaloterakis



Flying with Half the Fuel

BOX WING JET, LOCKHEED MARTIN

TARGET
DATE
2025

Passenger jets consume a lot of fuel. A Boeing 747 burns five gallons of it every nautical mile, and as the price of that fuel rises, so do fares.

Lockheed Martin engineers developed their Box Wing concept to find new ways to reduce fuel burn without abandoning the basic shape of current aircraft. Adapting the lightweight materials found in the F-22 and F-35 fighter jets, they designed a looped-wing

configuration that would increase the lift-to-drag ratio by 16 percent, making it possible to fly farther using less fuel while still fitting into airport gates. They also ditched conventional turbofan engines in favor of two ultrahigh-bypass turbofan engines. Like all turbofans, they generate thrust by pulling air through a fan on the front of the engine and by burning a fuel-air mixture in the engine's core. With fans 40 percent wider than those used now, the Box Wing's engines bypass the core at

several times the rate of current engines. At subsonic speeds, this arrangement improves efficiency by 22 percent. Add to that the fuel-saving boost of the box-wing configuration, and the plane is 50 percent more efficient than the average airliner. The additional wing lift also lets pilots make steeper descents over populated areas while running the engines at lower power. Those changes could reduce noise by 35 decibels and shorten approaches by up to 50 percent.—ANDREW ROSENBLUM



140TH ANNIVERSARY

FROM THE ARCHIVES

The Future Then

December 1982

The *Monera*, an ultralight glider kit designed to keep costs down for model-airplane enthusiasts

The Future Now

A hybrid plane that emits 60 percent less carbon dioxide—and keeps costs down for airline passengers





Bringing Back Supersonic

SUPERSONIC GREEN MACHINE, LOCKHEED MARTIN

TARGET
DATE
2030

The first era of commercial supersonic transportation ended on November 26, 2003, with the final flight of the Concorde, a noisy, inefficient and highly polluting aircraft. But the dream of a sub-three-hour cross-country flight lingered, and in 2010, designers at Lockheed Martin presented the Mach 1.6 Supersonic Green Machine. The plane's variable-cycle engines would improve efficiency by switching to conventional turbofan mode during takeoff and landing. Combustors built into the engine would reduce nitrogen oxide pollution by 75 percent. And the plane's inverted-V tail

and underwing engine placement would nearly eliminate the sonic booms that led to a ban on overland Concorde flights. The configuration mitigates the waves of air pressure (caused by the collision with air of a plane traveling faster than Mach 1) that combine into the enormous shock waves that produce sonic booms. "The whole idea of low-boom design is to control the strength, position and interaction of shock waves," says Peter Coen, the principal investigator for supersonic projects at NASA. Instead of generating a continuous loop of loud booms, the plane would issue a dull roar that, from the ground, would be about as loud as a vacuum cleaner. —ANDREW ROSENBLUM

HIGH VOLTAGE

Inside the first production-ready electric airplane

Engineers have historically faced two obstacles when designing electric aircraft. Batteries that run the electric motors have been too heavy and not energy-dense enough to provide sufficient power. And the consequences of failure were too high: Running out of power would all but assure a crash landing.

But in the past several years, says Paul Peterson, the founder and CEO of the Portland, Oregon, aeronautics company Volta Volare, off-the-shelf electric-car batteries and motors have become light, powerful and efficient enough to make electric—or at least hybrid—flight viable. This spring, Volta Volare will begin testing its four-passenger GT4. Constructed around a standard airframe, the plane runs on a hybrid powertrain similar to the one in the Chevrolet Volt, with batteries plus a backup gasoline engine.

An electric plane could be significantly less expensive to operate than a conventional aircraft. A 200-mile electric-powered flight in a single-engine personal plane would consume about \$20 of electricity, compared with about \$80 worth of aviation-grade gasoline, and an electric motor has only one moving part, so it would be largely maintenance-free. Peterson says that such cost reductions, combined with shared-ownership models, could make personal aviation vastly more accessible.



STORY BY Seth Fletcher | ILLUSTRATION BY Daniel Schumpert and Jason Briney

CANARD PUSHER AIRFRAME

Peterson's team settled early on a canard pusher airframe—so named for the canard, or short cross-wing near the plane's nose, and the rear-mounted propeller, which "pushes" the craft through the air. The airframe's "three-wing" design affords engineers a multitude of places in which to stash batteries.

CARBON-COMPOSITE PROPELLER

The GT4's four-blade carbon-composite propellers are lighter than those made of metal or wood, but they are strong enough to handle the heavy, instantaneous torque that electric motors produce.

HYBRID POWERTRAIN

The GT4 can take off, climb, and cruise up to 300 miles on battery power alone. When the power supply approaches 25 percent full, a battery controller signals the gas engine to kick in. The engine generates electricity, which recharges the battery.



ELECTRIC MOTOR

The GT4's electric motor, which is made from the combined cores of two smaller motors, sits in a sealed aluminum housing. It can generate 600 peak horsepower and sustain 400 horsepower throughout flight. Unlike an internal-combustion engine, which requires a mechanic to spend a week dissecting and then reassembling the powertrain during annual inspections, the electric motor on the GT4 would involve just a quick electronic diagnostic by connecting a laptop to the plane by USB cable.

ELECTRIC-CAR BATTERIES

A 900-pound lithium-polymer battery array—236 individual cells, each the size of a paperback book—powers the electric motor. The GT4's hybrid powertrain is lighter than the gas engine that the canard pusher airframe was originally designed to carry, so engineers added extra batteries to balance the craft's center of gravity. "In the old days," Peterson says, "the pilot would move bags of lead shot in and out of the luggage compartment. Now we can use batteries for that."

RANGE-EXTENDING GAS ENGINE

A supercharged 1.5-liter gasoline engine backs up the electric system. A 23-gallon tank in the center fuselage holds enough unleaded gas to extend the GT4's range up to 1,000 miles. Once batteries improve, engineers could remove the gas engine, converting the GT4 into an all-electric craft.

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THE FUTURE OF THE ENVIRONMENT

BUILDING A BETTER WORLD

How to Survive and Prosper
on a Warming Planet

✓ **HUNGER**

Grow 12 Trillion Calories a Day
P. 49

✓ **THIRST**

Store 366 Quintillion Gallons of Water
P. 52

✓ **OVERCROWDING**

Construct 9 Billion Apartments with a View
P. 46

The award-winning
LO2P Recycling
Center concept



Hellfighters
of Chernobyl

The War Over
Climate Science

But Everything's OK:
Self-Chilling Beer!



5,000

Number of balloons required to lift a 150-pound person

(a general term for all steerable airships) still require ground crews—guys with ropes and ballast. If Pasternak's variable-buoyancy system works, the pilot will be able to maneuver in all directions, vertically and horizontally, with no external assistance. He will be able to go anywhere and land anywhere, and take a very big cargo along with him. "Then you have progress," Pasternak says.

Revolutionizing transportation with airships is an old idea but a persistent one, and it's usually the military that brings it closer to reality. More than a century after George Griffith described armed conflict fought with "war balloons" in his popular novel *The Angel of the Revolution*, the U.S. military was considering the merits of transporting materiel with airships. In 2005 Darpa, the Pentagon's experimental branch, initiated Project Walrus and set about finding a contractor to build a "hybrid ultra-large aircraft" that could transport 500 tons of cargo at least 12,000 nautical miles. Pasternak's Aeros got the biggest contract of the project. ("There is only one solution," Pasternak had explained to the *Los Angeles Times*, "and we have that one solution.") But in 2010, the Pentagon chose not to renew Project Walrus, a fate not uncommon to airship schemes.

Builders around the world nonetheless continue to investigate various ways to get airships off the ground. Northrop Grumman, Lockheed and other major aviation companies, alongside such smaller entrepreneurs as Cargolifter and Aeros have all at various times participated in the race to build a commercially viable airship.

Bill Crowder, a logistics expert who is inspecting the Aeros prototype with us today, has been following Pasternak's efforts for years. Logistics is the industry term for the business of getting the world's freight and equipment where it needs to go. Imagining the sky filled with *Titanic*-size dirigibles induces "the giggle factor," Crowder now says, craning his neck up toward the frame, but that doesn't mean it's not a good idea. And in fact, a ship like this could stay in the air for a week and then deliver a substantial payload—a 50-ton crane, say, that's needed in the Arctic.

Pasternak launched Worldwide Aeros Corp. in Ukraine in 1987 and at first made just unmanned "aerostats," small tethered blimps. He moved the company to the U.S. shortly after the collapse of the



CONTINENTAL DRIFT

The first customers for Aeroscraft airships will be cargo companies, but the vehicles could eventually be developed into flying hotels that silently transport guests from New York to Los Angeles overnight.

"I always wanted to build the Aeroscraft. I put all the profit of my company into this new ship. Everything."

Soviet Union and, in a moment of détente, became the lead Pentagon contractor for the development of lighter-than-air vehicles. Aeros is the biggest seller on Earth both of aerostats and manned blimps—its customers include the U.S. Department of Defense and authorities in several foreign governments—but all of that, Pasternak says, is a means to an end. "I always wanted to build the Aeroscraft," he says. "I put all the profit of my company into this new ship. Everything."

For the moment, his ship is leading the race. Cargolifter went out of business, as did Advanced Technologies Group, the U.K.'s main firm attempting to

revive airship innovation. Lockheed and Northrop have fixed their sights on a type of airship that still requires a runway. "None of them have the capability of the Aeroscraft," Pasternak says.

The widely used C-17 cargo plane can carry 75 tons. The one-off Soviet AN-225 can carry a record-breaking 275 tons. But if the Aeroscraft prototype works and Pasternak completes plans to build an 800-foot model, he will advance the capacity of airborne transportation to 500 tons, delivered anywhere. "This is a lovely sight to a logistics guy," Crowder says. "I've been waiting for something like this for a long time." ●

PART 2

Build Smarter Cities

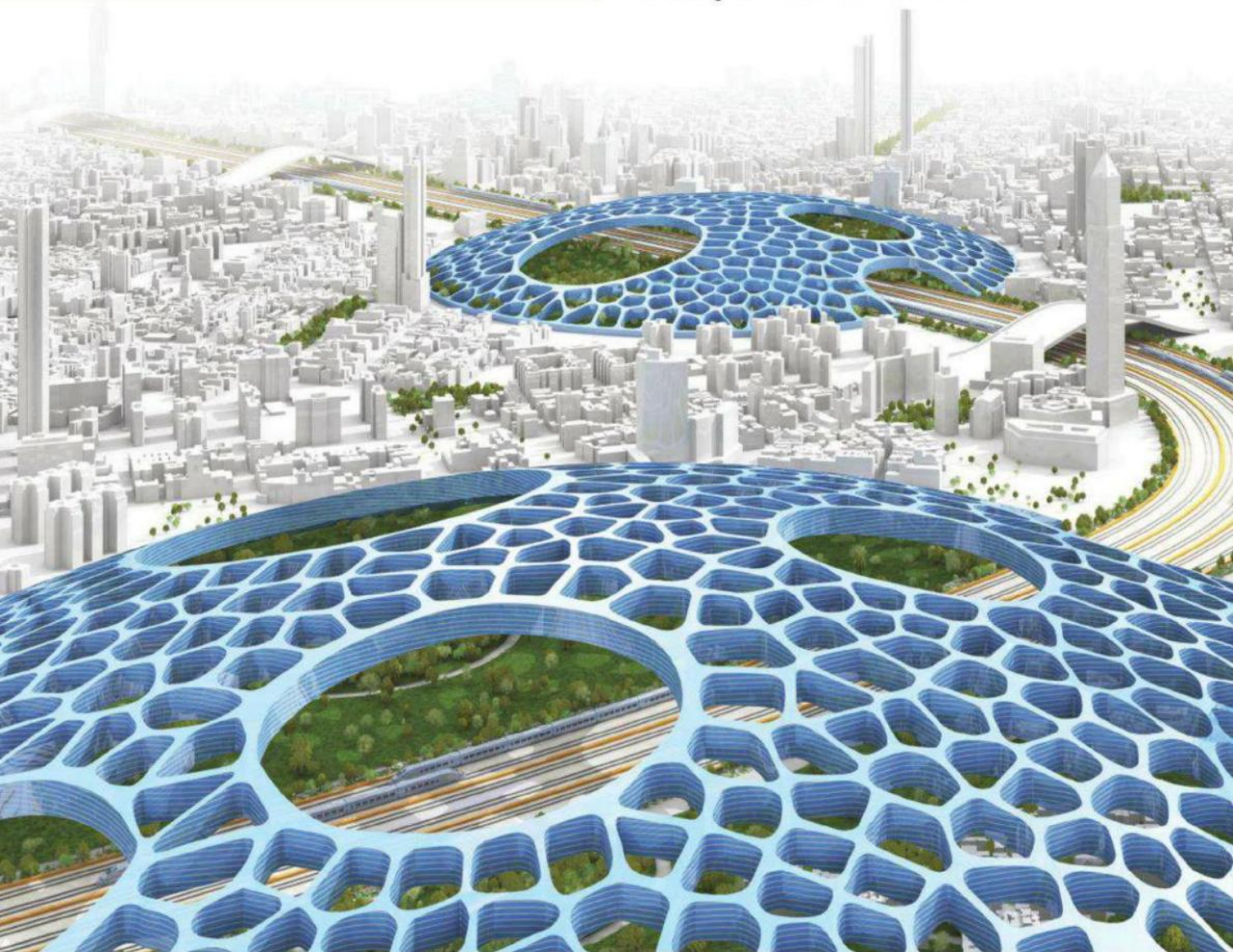
Climate change will drive people to urban areas. How will urban planners accommodate them all?

STORY BY Kalee Thompson

ILLUSTRATION BY Bryan Christie



The world's population will top nine billion by 2060. Because of climate-change-induced environmental degradation, scientists project that tens of millions of people will move into today's small and medium-size cities. To prepare for the influx, says Dennis Frenchman, an architect and professor of urban planning at MIT, city designers must make decisions today to mitigate the migration of tomorrow. And those decisions should focus on making systems more efficient. Transportation networks need to be rethought to limit congestion. Politicians should offer incentives to manufacturing firms to relocate to city centers to decrease the number of commuters. Power generation and food production should become local, too; reducing transmission and transportation costs would keep prices lower. Further, Frenchman says, single-purpose-use spaces like shopping centers and housing developments should be swapped for mixed-use neighborhoods that contain homes, medical offices, stores, schools and offices. With essential services packed into one relatively small area, even the densest city would feel more like a small town.



To make super-dense cities more livable, designers will need to rethink every last square foot.



Community-Shared Electric Cars

Lots of people, each with a private car, means lots of traffic, pollution and wasted space in the form of parking lots. The designers of the MIT Media Lab prototype CityCar say communal microcars will alleviate crowded roads. The two-seat, all-electric CityCar is best used for point-to-point trips within a few-mile radius. When not in use, the car folds up and stacks together with other CityCars.



Neighborhood Nukes

Power lines can lose up to 425 kilowatts per mile of cable. To reduce loss and keep energy prices lower, cities must integrate power generation into neighborhoods. One possible power source is a microsize nuclear power plant, such as GE Hitachi's PRISM. The PRISM's reactors would use recycled nuclear fuel to generate 300 megawatts—enough to supply 240,000 homes.



Hyperefficient Housing

As more people crowd into cities, average apartment size will decrease, probably to about 300 square feet, Frenchman says. To make such a small area feel less cramped, every space in the home must be multifunctional. For example, furniture could fold out of walls, and windows made from transparent OLEDs, like ones that Samsung first demonstrated in 2010, would serve as a TV or could be made opaque on command to reduce cooling costs.



Really Local Eats

To keep food-transportation costs down, engineers should construct vertical farms, such as the ones proposed by Columbia University public-health professor emeritus Dickson Despommier, that could provide fresh produce and fish to local neighborhoods. Apartment residents will grow personal gardens on the facade of their buildings with pre-seeded panels plugged into built-in wall slots, says Kent Larson, an architect at the MIT Media Lab.



All-in-One Recycling

Recycling will limit material waste, but the process is energy-intensive. In the LO2P Recycling Center, envisioned by designers Gael Brule and Julien Combes, a turbine harnesses wind power to run a recycling plant in the building, while carbon dioxide from the plant reacts with calcium to become lime in the LO2P's mineralization baths. Calera Corporation in California developed the process and today uses the lime to make cement.



Multifunctional Buildings

The mixed-use concept is the basis for architect Paul-Eric Schirr-Bonnans's Flat Tower. In addition to having offices, recreation areas and a rail transit hub, the Flat Tower could house 40,000 people. Schirr-Bonnans says that the conventional skyscraper model—a tower surrounded by green space—leads to the isolation of communities from one another. A greenbelt area under the building would encourage communities to interact.

The LO2P won first prize in the 2011 Skyscraper Competition, sponsored by design journal *eVolo*. The Flat Tower won second prize in the same competition.



PART 5

And If All Else Fails

It's 115 degrees. In March. Now what?

STORY BY Damon Tabor

ILLUSTRATION BY Graham Murdoch



IT'S IMPOSSIBLE to predict the exact speed and severity with which climate change will unfold, but one thing is clear: if we take no preventive action, eventually we'll be tempted to take desperate action. And over the decades, as the effects of climate change grow increasingly severe, the amount of risk humankind is willing to bear will increase.

In the next decade, as Dust Bowl-like conditions afflict the American West and it becomes ever more difficult to dismiss the drought as a temporary glitch, low-risk methods for removing carbon dioxide from the atmosphere will start to look attractive. The most benign scheme would be to plant more trees. In 1976, physicist Freeman Dyson proposed planting a tree farm the size of Australia to offset the fossil-fuel emissions of the day. By 2009, NASA climate modelers and biologist Leonard Ornstein estimated that both the Australian outback *and* the Sahara would have to be transformed into forest to remove meaningful quantities of carbon dioxide. They proposed irrigating both deserts with desalinated seawater and planting them with eucalyptus forests, which could remove as much as 12 billion tons of CO₂ from the atmosphere every year—about a third of the total global emissions in 2010. Nuclear power plants could generate carbon-free electricity for the network of reverse-osmosis desalination plants. This world-historical landscaping project would carry risks. An afforested Sahara could provide a breeding ground for swarms of crop-destroying locusts and flocks of disease-carrying birds. Because Saharan dust may help suppress Atlantic cyclone formation, the scheme could strengthen hurricanes. The biggest problem, however, may be the \$1-trillion-plus annual cost.

A cheaper method would be ocean fertilization—dumping iron dust into the sea to stimulate the growth of CO₂-breathing phytoplankton. Over the past two decades, scientists have conducted more than a dozen small-scale trials to confirm that



**DESPERATE
MEASURES**
Bombarding the
stratosphere with
aerosol-packed
artillery shells could
either lower the
temperature of the
planet—or destroy it.

